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THE ANATOMY OF THE SACRO-UTERINE LIGAMENTS

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TWENTY-TWO FIGURES

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I. INTRODUCTORY

A great deal has been written upon the anatomy of the pelvic floor and the mechanical supports of the pelvic viscera. While all of the contributors have more or less advanced our knowledge of the anatomy of the pelvis, all have failed to completely elucidate the anatomical and physiological importance of the fibro-elastic tissue that forms a more or less dense mesh-work, filling up the interval between the peritoneum above; the pelvic diaphragm covered by its facial sheath below; the obturator fascia and periosteum of the innominate bone laterally; the bladder, vagina, and uterus with their fibrous investment medially; and finally, the fascia over the sacral promontory, sheath of the sacral plexus, and fibrous tunic of the rectum, posteriorly. Cameron and Moritz have made the nearest approach to the proper solution of the question, but they failed in not subjecting the 'compact mass' filling up the interval between the peritoneum and pelvic floor as above limited to the proper anatomical analysis.

The primary object of the present investigation is the study of the so-called sacro-uterine ligaments; to determine what they really are and to establish their relation to the transverse ligaments of the uterine neck, recto-uterine muscles and recto-uterine folds.

II. METHODS OF STUDY AND MATERIAL

From a survey of the work which has been done, it is evident that a comparative and a more comprehensive study is absolutely necessary for the proper solution of the problem. In accordance with that view, cadavers that had been embalmed in the usual manner for dissection, and others preserved with 10 to 40 per cent solutions of formaldehyde, and fresh material in and from the autopsy room, were used. Recent or unfixed material has the advantage of being perfectly flexible, permitting of experimental procedures not possible on the firm and inelastic material of the dissecting room. Finally, a careful study of frozen sections revealed some most interesting points.

The human material included fetuses, the new born, and cadavers of the following ages: 40 days, 10, 24, 35, 65, and 83 years. The animals most readily available were the guinea pig (Cavia cabayia), Belgian hare (Lepus europaeus), cat (Felix domestica), dog (Canis familiaris), and monkey (Macacus). In the whole series the parametrium containing the so-called ligaments and folds were cut in serial sections and subjected to a careful examination. Experimental observations on the pelvic organs were made on the animals while under an anesthetic.

Since the appearance of a preliminary report of this paper in June, 1913, there has been published an interesting paper by Moritz ('14), in which the author considers the distribution and significance of the parametrium. His method has been to obtain the pelvic contents as soon after death as possible, by having them removed right down to the bone and the pelvic floor cut away with them. The specimens were then fixed in 10 per cent solution of commercial formalin. Not 'dissected,' in the ordinary acceptation of the term, but sections were cut in varying planes and directions.

III. BRIEF REVIEW OF THE LITERATURE

a. Chronological

The more important contributors are the following:

Kocks, (1) ('80),
Hart, (2) ('80),
Mackenrodt, (3) ('95),
Holl, (4) ('97),
Harman, (5) ('98),
Thompson, (6) ('00–'06),
Deaver, (7) ('03),
Montgomery, (8) ('03),
Stony, (9) ('04),
Derry, (10) ('07),
Paterson, (11) ('07),
Ovenden, (12) ('07),
Cameron, (13) ('07–'08),
Smith, (14) ('08),
Fothergill, (15) ('08),
Somers and Blaisdell, (16) ('13),
Moritz, (17) ('14).

Kocks (1) described the cardinal ligaments. Mackenrodt (3) defined the ligamentum transversale colli. Deaver (7) states that the false posterior or recto-uterine ligaments are composed of two peritoneal layers which pass backward from the posterior surface of the uterus and vagina to the upper portion of the rectum, forming the lateral boundaries of the pouch of Douglas; external to each are found the true or muscular utero-sacral ligaments, which are flat muscular bands that extend from the uterus at the level of the internal os, to the sides of the sacrum, passing beneath the layers of the recto-uterine ligaments.

Montgomery (8) says that the utero-sacral ligaments, while consisting of folds of peritoneum, also contain muscle fibers, which are derived from the superior muscular layer of the uterus.

Paterson (11) considered the suspensory ligaments. Ovenden (12) reviews Mackenrodt's work and states that the ligamentum transversale colli is worthy of being recognized as a distinct ligament, and that the utero-sacral ligament blends with the former near its insertion into the uterus.

Cameron (13) considers the utero-sacral ligaments as a part of the general perivascular mass.

Moritz (17) in criticizing Dr. Ovenden's views states: "I hope to demonstrate that the sketch she published of the insertion of the ligament (transverse of the neck) shows clearly that the so-called ligament is simply a portion of the parametrium containing the uterine artery, artificially separated from the surrounding mass." He agrees that the parametrium constituting the ligamentum transversum colli is of great importance physiologically, in that they fix the cervix and form the most fixed point of the uterus. In a brief summary he states that: "the whole structure is nothing but an inseparable continuation of parametrium which surrounds and fixes the cervix." He considers the utero-sacral ligaments as small folds of peritoneum, and contain nerves, perineural connective tissue and smooth muscle; they carry the nervi erigentes, pushing their way through the mesodermal tissue from their points of emergence from the anterior sacral foramen.

b. Descriptive and topographical

The descriptive and topographical statements by Cunningham (19) of the connections of the uterus and its relations to the peritoneum laterally and posteriorly may be taken as the consensus of opinion among anatomists. The deep pouch between the uterus and vagina in front and the rectum behind is called the pouch of Douglas (excavatio recto-uterina) and its entrance is bounded on each side by a crescentic peritoneal fold, which passes from the posterior surface of the cervix uteri to the posterior wall of the pelvis, and ends near the side of the rectum. These crescentic folds are called the recto-uterine folds (plicae recto-uterinae), and each contains between its layers a considerable amount of fibrous and smooth muscular tissue. Some of these fibers, which are continuous with the uterine wall, pass backward to reach the rectum and constitute the recto-uterine muscle (ligamentum sacro-uterinum). In many cases the recto-uterine folds become continuous with one another across the middle line behind the cervix uteri, and form a transverse ridge termed the torus uterinus.

A comparison of Morris (20), Piersol (21), and Gray (22) with Cunningham (19) and others, inevitably leaves the student in doubt as to what really constitutes a sacro-uterine ligament and its relation not only to the plica recto-uterina but the musculus recto-uterinus as well.

Morris (20) calls the posterior peritoneal folds of the uterus, 'the recto-uterine ligaments,' and states that they become continuous with the peritoneal investment of the second part of the rectum, and that between their layers lie the utero-sacral ligaments, the latter being flat fibro-muscular bands, extending from the highest part of the cervix uteri, where they are more or less continuous with the uterine fibers in the recto-uterine peritoneal folds, to the sides of the sacrum

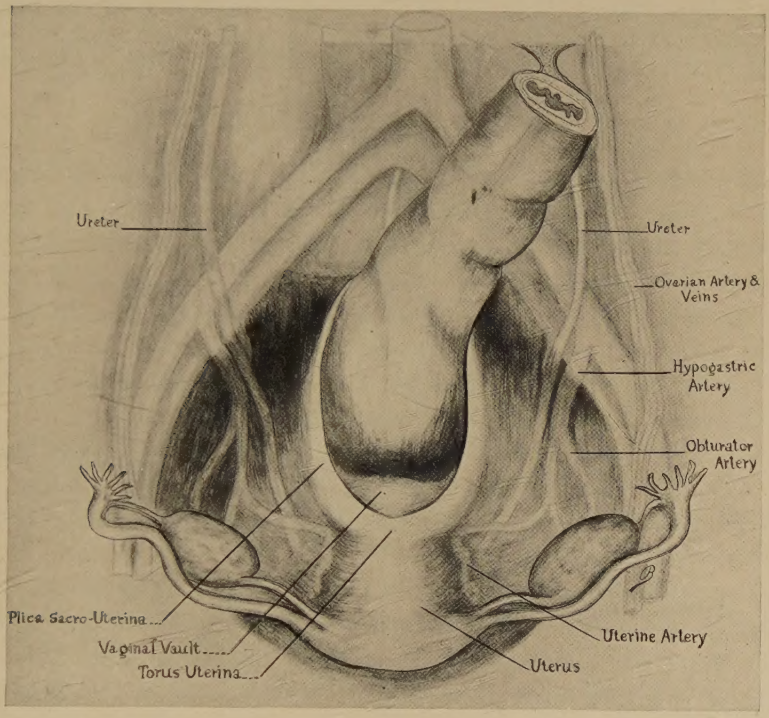

Fig. 1 Semi-diagrammatic drawing of female pelvic viscera viewed from above, uterus and adnexa being drawn forward and vessels projected against peritoneum.

opposite the lower border of the sacro-iliac articulation. They run one on each side of the rectum near the junction of the first and second parts. Their muscle fibers (the recto-uterine muscles) become continuous with those of the rectum posteriorly and more anteriorly they lie in the recto-uterine peritoneal folds, which form the lateral boundaries of the pouch of Douglas.

Piersol (21) states that between the layers of the folds (plicae-recto-uterinae) robust bundles of fibrous and smooth muscular tissue

extend from the uterus to be inserted partly into the rectum, these constituting the utero-rectal muscle, and partly into the front of the sacrum as the utero-sacral ligament.

Gray (22) says that the sacro-uterine ligaments (plicae-recto-uterinae) are contained in the peritoneal folds of Douglas. They pass from the second and third bones of the sacrum, downward and forward on the lateral aspects of the rectum to be attached one on each side of the uterus at the junction of the supra-vaginal cervix and the body. They contain fibrous tissue and unstriated muscle fibers. Muscular fibers from the uterine wall to the rectal wall constitute the recto-uterine muscle. This muscle is part of the sacro-uterine ligaments.

IV. EXPLANATORY REMARKS

The terms cardinal ligament, ligamentum transversale colli uterini and suspensory ligament are synonymous. The parametrium includes all of the fibro-elastic tissue lying lateral to the uterus; the paravaginal tissue that which lies opposite the vaginal vault; while the term paraplical will likewise signify the tissue lateral to the recto-uterine folds, or more specifically that lying lateral to the recto-uterine fossa and fibrous tunic of the rectum. It fills the subperitoneal cavity as defined by Moritz.

The sacro-uterine and recto-uterine folds are the same structurally, the only difference being the manner of termination, which makes it necessary from a physiological standpoint to speak of them separately.

The term fibro-elastic will be used instead of Cameron's (13) term perivascular tissue, because the term perivascular defines only a part of the parametrial supporting tissue, and its function is not primarily to support blood vessels as will be explained later.

V. COMPARATIVE SERIES

In animals, which habitually assume the horizontal position in locomotion, there is to be found a simpler and less condensed condition of the uterus as regards bulk than in those animals which assume the erect position. Such animals possess either two uteri or a uterus bicornis. The uteri are therefore comparatively less bulky and the weight is distributed along a more extensive peritoneal attachment. Such attachment usually ex-

tends as far cephalad as the caudal pole of the kidneys. At all times, except during short periods of time when other than the horizontal position is assumed, the weight of the uterus, distended bladder and rectum, cause these organs to fall ventrad in the hypogastric region of the abdominal cavity. The uterus in a state of physiological rest is relatively light and consequently there is less need of true or fibrous ligaments, such as are present in the higher Primates, where the uterus is more con-

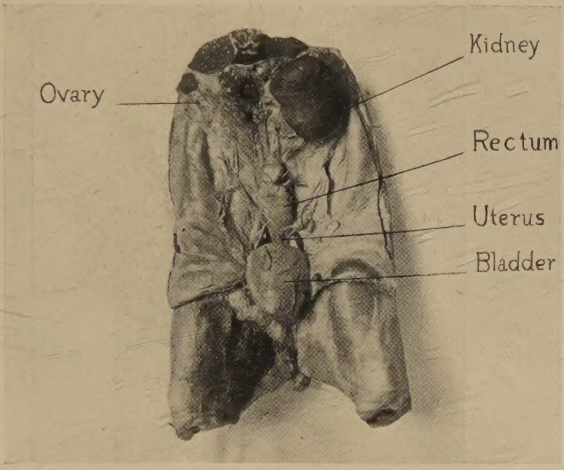

Fig. 2 Photograph showing relations of rectum, bladder and extensive peritoneal attachment of uterus in an animal which assumes the horizontal position in locomotion. Dog (Canis familiaris).

centrated in bulk and weight, and the erect position is assumed habitually, except during limited periods.

Therefore, in animals possessing a uterus bicornis, the peritoneal reflections are sufficient with a very meager amount of parametrial tissue to maintain the normal position of the organ. In the small series of animals examined during the preparation of this paper, one very important and significant fact was determined, and that is, that there were always bundles of smooth muscle fibers present in the peritoneal folds passing dorsad from the vagina to the rectum. Laterally, in the parametrial and paravaginal tissue, such bundles were practically

absent and the fibro-elastic bundles were reduced to a minimum. It is therefore logical from an evolutionary standpoint to conclude that the presence of the recto-uterine muscle in these folds appears at an early date in the vertebrate series, and that they possess a phylogenetic significance.

1. GUINEA PIG

In the guinea pig, two distinct peritoneal folds pass dorsally from the sides of the vagina to the sides of the rectum. They

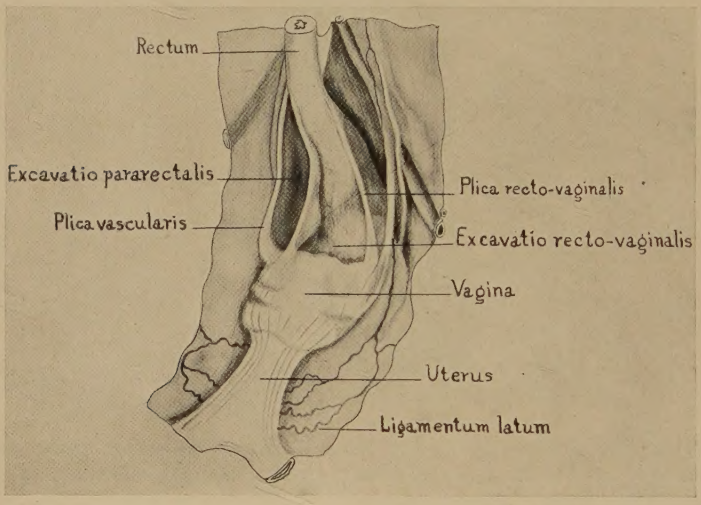

Fig. 3 Drawing showing rectum, vagina, uterus, recto-vaginal pouch and recto-vaginal folds in guinea pig (Cavia cabayia).

are therefore recto-vaginal folds, and must be termed the lateral folds to distinguish them from the median recto-vaginal reflection of peritoneum at the bottom of the recto-vaginal fossa. Lateral to the rectum and recto-vaginal fold is the pararectal fossa, which is in turn bounded laterally by a peritoneal fold conveying utero-vaginal blood vessels. The lateral recto-vaginal folds and broad ligaments of the uterus are extremely thin and more or less transparent to translucent. By means of serial microscopical sections bundles of smooth muscle fibers

have been traced from the uterus toward the rectum, in the recto-vaginal folds. These delicate muscular fasciculi are continuous with the noticeable longitudinal fibers on the dorso-lateral facies of the uterus. It is important to note that the stratum fibrosum of the peritoneum shows marked thickening. The few muscular fasciculi that do reach the sides of the rectum may be traced along its lateral wall to be inserted into its fibrous sheath, or continuing dorsally, become lost in the meso-rectum. Many of the fasciculi diminish in size as they pass through the folds, their fibers apparently becoming inserted into the peritoneum, but their actual termination has not been observed. Between the two peritoneal layers of the recto-vaginal folds there is a small amount of extremely fine areolar tissue with a few fibro-elastic filaments. In the parametrial and paravaginal tissue there is a very meager amount of fibro-elastic elements. The cephalic extremity of the vagina is freely movable and lies between the bases of the broad ligaments. The recto-vaginal folds varied quite a good deal in size and symmetry in the different guinea pigs examined.

2. BELGIAN HARE

Distinct recto-vaginal folds are present. These and the broad ligaments are thin and more or less transparent, containing a varying amount of adipose tissue. Visible fibers are very sparse in the parametrial and paravaginal tissue. The free margins of the recto-vaginal folds are slightly thickened and opaque, as in the guinea pig. This opacity is due to temporary aggregation of the muscular fasciculi. The stratum fibrosum of the peritoneum constituting the folds, shows distinct thickening and at its deep surface passes insensibly into the extremely delicate areolar tissue between the layers, where also a few fibro-elastic bundles are found. In the parametrial and paravaginal tissue, there is a varying paucity of fibro-elastic bundles, but no fibers that could be taken to constitute potential ligaments, or noticeable aggregations of fibers to constitute true ligaments are present (fig. 5). The fasciculi of the recto-uterine muscle vary

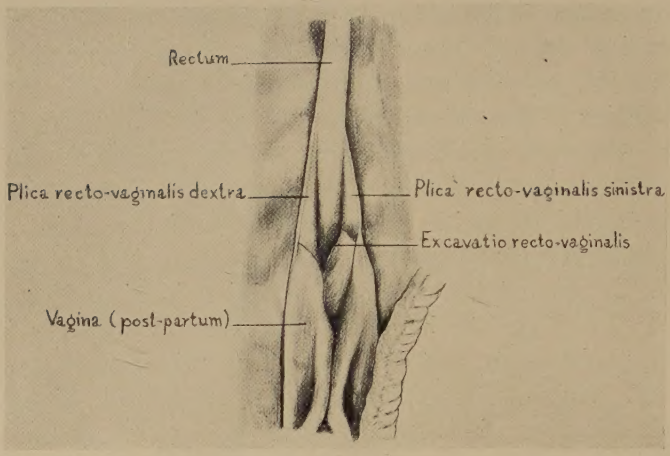

Fig. 4 Drawing showing rectum, vagina (post-partum) and recto-vaginal folds in Belgian hare (Lepus europeaus).

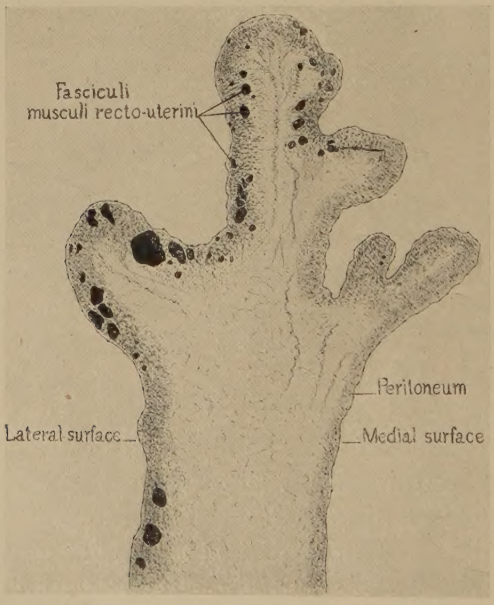

Fig. 5 Transverse section of a lateral recto-vaginal fold at middle third, showing distribution of fasciculi of recto-uterine muscle. Belgian hare. ×62. Reduced to one-third.

greatly in size and are distributed chiefly in the apical and lateral peritoneal layers of each fold. Many of the fasciculi appear to be almost submesothelial, others which are in the minority appear to be on the inner border-line of the stratum fibrosum, the majority however are in the more central parts of that layer. The muscular fasciculi are abundant in the vaginal extremity of the recto-vaginal fold, but become greatly diminished or absent in the rectal extremity of the same. A large percentage of the fasciculi therefore terminate in the fold probably by insertion into the more superficial part of the stratum fibrosum. Their actual termination has not been observed.

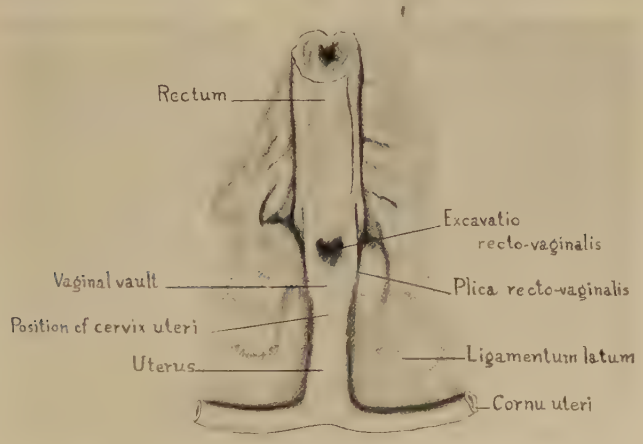

Fig. 6 Rectum, vagina and uterus of cat (Felis domestica), showing recto-vaginal folds.

3. CAT

The recto-vaginal folds are thicker and relatively smaller than in the hare, and pass more noticeably upon the ventral surface of the rectum; they are transparent as are also the broad ligaments. The recto-uterine muscles form distinct bands and attain the sides of the rectum; they are fusiform in transverse section and each carries its own blood-vessels. The stratum fibrosum of the peritoneum is distinctly thickened and contains the muscular fasciculi. The fasciculi are most abundant and

largest in the vaginal extremity of each fold, but many reach the side of the rectum and continue upon the same for a varying distance. They are not all in the prominent part of the fold on the rectum, for as the peritoneum spreads out the fasciculi necessarily go with it. The recto-vaginal folds vary in prominence and the distance to which they extend cephalad on the rectum depends on the degree of distention of the latter. It has

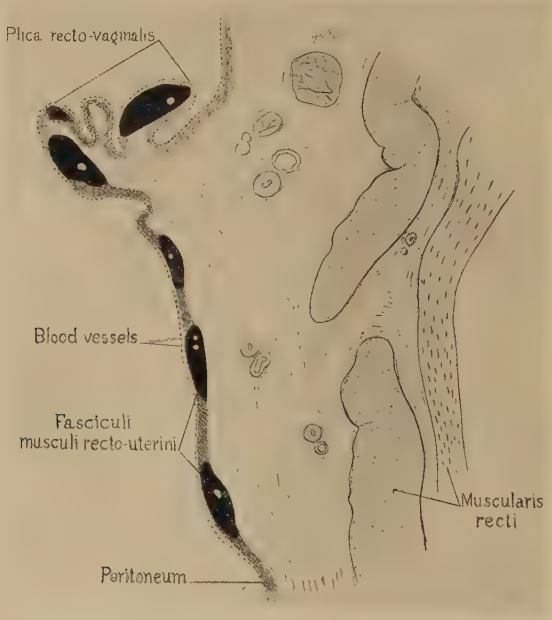

Fig. 7 Semi-diagrammatic drawing of lateral wall of rectum of cat, showing peritoneum and fasciculi of recto-uterine muscle, recto-vaginal folds and muscularis recti (Transverse section). × 175. Reduced to one-third.

been observed that the peritoneum is anchored to the rectum by fibrous trabeculae which arise in the intermuscular fibrous tissue of the muscularis, which by passing outward, through intervals in the longitudinal layer become inserted into the stratum fibrosum.

Figure 8 shows the details of a muscular fasciculus, and its more or less centrally located blood vessel. In the majority of cases the vessels are intra-fascicular, but they vary in position to the periphery and may be supra-fascicular.

4. DOG

In the dog, the anatomical relations between the pelvic viscera differ considerably from those in the series described above. The vagina during the inter-estral period is rather firmly fixed at its cephalic extremity. The bladder has a short but distinct neck, the peritoneum being reflected from the cervix vesicae upon the anterior vaginal wall before attaining the uterus. In the individuals examined small single or double recto-vaginal folds passed from the utero-vaginal junction to the rectum. The

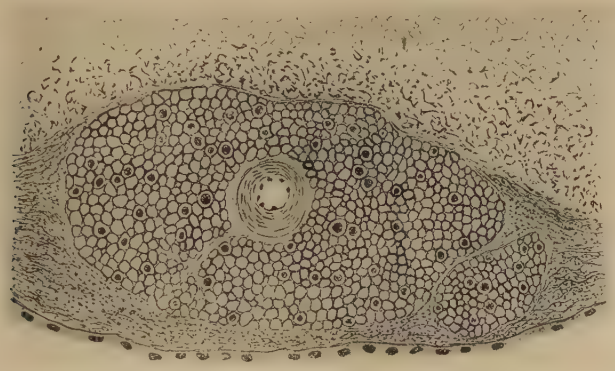

Fig. 8 Detailed camera lucida drawing of a fasciculus of recto-uterine muscle with its blood vessel, showing relation to peritoneum (Transverse section). Cat. × 235. Reduced one-half.

ligaments of the bladder and uterus are thin, transparent and contain a varying amount of adipose tissue. The bladder possesses well developed dorso-lateral ligaments which suspend it from the dorsal pelvic wall. The uterus is held in close relation to the ventral surface of the rectum, by its relatively large broad ligaments which pass from the sides of the cervix and cornua, each crossing the dorso-lateral ligament of the bladder of its own side. The recto-uterine muscles pass nearly directly between the two organs, and in the small single or bilateral recto-vaginal folds; or when one or both are absent by way of the peritoneum at the bottom of the recto-vaginal fossa. There is a broad recto-uterine space. Between the folds of the broad liga-

ments and in the parametrium there is relatively a little more fibro-elastic tissue, but no aggregations which might be construed as constituting true or potential ligaments.

5. GENERAL CONSIDERATIONS

From the study of the above comparative series the following facts are to be noted. Distinct recto-vaginal folds pass from the dorsal wall and cephalic extremity of the vagina to the rectum, the former being more or less free and movable; that these

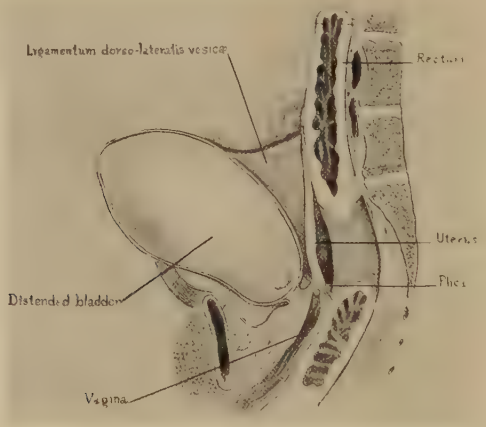

Fig. 9 Drawing of sagittal section of pelvis of a bitch showing relations of viscera and peritoneal folds.

recto-vaginal folds vary in size, and that they can be increased by traction on the uterus or more so by traction on both uterus and rectum. The stratum fibrosum of the peritoneum has in all cases undergone thickening or hypertrophy, and the fasciculi of the recto-uterine muscle are contained in it. The fasciculi of the latter are most abundant at the vaginal extremity of the fold and diminish in size and number as the rectum is approached, in some cases not reaching it. Some of the fibers of the muscular fasciculi are apparently inserted into the stratum fibrosum of the peritoneum, fewer of the bundles possibly being inserted into the fibrous tunic of the rectum or lost in the mesorectum.

The fibro-elastic tissue constituting the parametrial, paravaginal and paraplical tissue is very scanty in amount and does not form aggregations to constitute so-called true ligaments, nor in sufficient quantity to form potential ligaments. The body of the vagina is more firmly attached than the cephalic extremity.

VI. PRIMATE SERIES

1. MONKEY (MACACUS)

In the monkey, the uterus is undivided and the anatomical conditions are similar to those in the human female. The weight of the uterus is localized and therefore calls for stronger mechanical support. There is marked increase in the amount of the parametrial, paravaginal and paraplical fibro-elastic tissue, which can be recognized as constituting potential ligamentous aggregations. The specimens examined had unfortunately been embalmed in the usual way, but nevertheless the material demonstrated that the structure and relations were similar to those in the human female. Recto-uterine or sacro-uterine folds were absent, although potentially present. A short plica was present on each side at the utero-vaginal junction. These folds are not always present in woman, but can always be demonstrated as being potentially present, for traction forward on the uterus brings them into prominence. The thickened peritoneum with the recto-uterine muscles are always present.

The histological examination of the material from the monkey was not satisfactory as to details, on account of the amount of cytolysis and softening of the tissues generally, but everything indicated similar structural conditions as in woman.

2. HUMAN

For the purpose of establishing a point of departure, the pelvic structures in a state of full maturity or development in woman, will first be taken up, followed by those before maturity and, lastly, those in the stage of senility.

a. Examination of the structures in a recent post mortem state

The careful dissection of the pelvic viscera of a woman 35 years old gave the following results: The recto-uterine folds were moderate in prominence and diminished gradually, to become lost in the general plane of the peritoneum without attaining the posterior pelvic wall. The rectum was median in position and without a mesorectum opposite the third sacral vertebra.

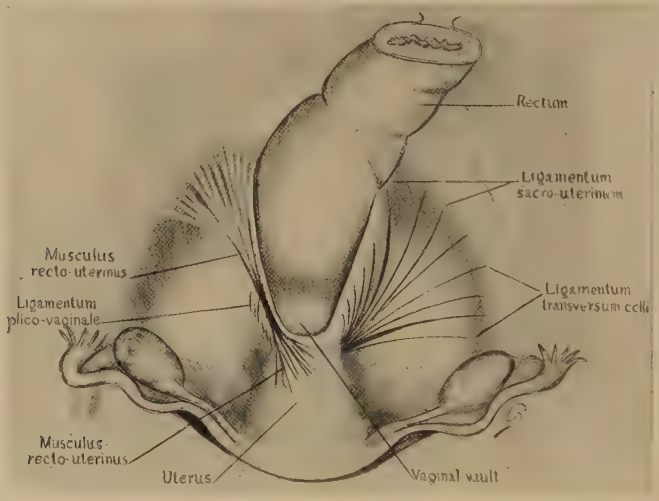

Fig. 10 Semi-diagrammatic drawing of female pelvic viscera viewed from above, uterus and adnexa having been drawn strongly forward. Position of potential ligaments are shown in black lines.

Traction forward on each sacro-uterine fold separately, tightened the peritoneum and raised its surface into a series of small ridges, that radiated toward the sacro-iliac junction and lateral border of the promontory, from the point where the fold disappeared, in a direction downward and inward to the middle of the second sacral vertebra at the edge of the rectum and reflection of the peritoneum upon it. The area raised on the right was triangular but did not extend so far laterally as given in figure 10; on the left side the raised area was narrower and less triangular than on the right. Traction backward on each fold

tightened the peritoneum about the uterine cervix and vaginal vault, raised the cervix upward and backward, forced the fundus against the bladder and raised the vaginal vault.

Traction on the uterus to the right or left simply tightened the broad ligaments, peritoneum, and subperitoneal fibro-elastic tissue without any special result.

Bodies embalmed in the usual way for dissection, or with a 10 per cent to a 40 per cent formaldehyde solution, will usually show the same result of traction on the sacro-uterine or recto-uterine folds, and parametrial fibro-elastic tissue as above stated. The embalming fluids used, especially the formaldehyde solution, produced marked contraction of fibro-elastic tissue and such contraction produces bands which are rendered slightly prominent as peritoneal ridges, more or less above the general surface contour of the peritoneum, the results varying in different cadavers. Two female cadavers in the anatomical collection of the university show these facts beyond doubt.

Traction per vaginum downward and forward on the uterus depresses the sacro-uterine or recto-uterine folds and draws on the sacral attachments of the peritoneum, in the line of the folds. At the same time there is a coincident appearance of a prominent ridge in each dorso-lateral wall of the vaginal vault, corresponding to the position of the sacro-uterine and plico-vaginal ligaments. There is a tightening of the subperitoneal tissue laterally as well as dorso-laterally to the uterus.

Reflection of the peritoneum lateral to the uterus and recto-uterine fold. uncovers a mass of fibro-elastic tissue, through which run the branches of the hypogastric vessels, lymphatics, and nerves on their way to the uterus, vagina and bladder. Traction in different directions on this mass demonstrated its great elasticity as well as the intrinsic movements of the fasciculi and lamellae over each other. Careful dissection and examination with a moderately strong hand lens clearly defined a mass of interlacing fibers and fasciculi ensheathing the vessels and nerves and having an attachment to the fascia covering the levator ani, coccygeus and obturator muscles, as well as the pre-sacral fasciae and peritoneum. Pulling on the fibro-elastic

tissue from different points laterally and at the periphery, drew the uterus in the same direction; drawing the uterus toward the opposite side of the pelvis tightened the fibro-elastic mass which appears to radiate chiefly from the sides of the uterine cervix, while traction toward the middle of the inguinal ligament tightened the fibro-elastic mass laterally and posteriorly on the opposite side.

The examination of several autopsy specimens not only verified the above facts but revealed others (fig. 10). By carefully cutting through the peritoneum in the anterior part of the lateral wall of the recto-vaginal fossa, dissecting out the areolar tissue filling in the meshes of the fibro-elastic net-work and isolating a number of fibers, a dimpling of the peritoneal surface along the sacro-uterine fold could be produced by pulling downward on the fibers. Other fibers appeared to be attached further posteriorly in the vicinity of the sacrum. Pulling upward on the same fibers raised the vaginal vault or the cervix uteri. These experiments determined that there were two sets of fibers which entered or passed beneath the fold. One set passing from the sides of the uterine cervix backward, giving off fibers which were inserted into the stratum fibrosum of the peritoneum along the line of the fold, and others reaching the presacral fascia. The second set passed from the sides of the vaginal vault below the above and inserted into the stratum fibrosum along the anterior two-thirds of the fold. The study also determined that the meshes of the fibro-elastic network varied in size and irregularity. At times there was observed an apparent increase in the density of the fibro-elastic mass opposite to the cervix uteri and vaginal vault. At the periphery of the pelvic cavity just in front of the sacro-iliac articulation, the network appeared less dense. This condition was not always evident.

In cadavers that have been embalmed in the usual way and dissected, there will be found fasciculi passing laterally from the side of the uterine cervix, and forming a more or less distinct band which corresponds in position to the cardinal ligament or ligamentum transversale colli. Other fasciculi which pass

backward beneath the sacro-uterine fold to reach the presacral fascia, correspond to the course of the so-called sacro-uterine ligament. The fibers sweeping downward from within the anterior two-thirds of the sacro-uterine fold to be inserted into the sides of the vaginal vault, are termed the 'plico-vaginal ligament.'

b. Histological observations. Fixed material

1. Adult 35 years old. Figure 11 is a photomicrograph of a portion of a transverse section of the sacro-uterine fold of a

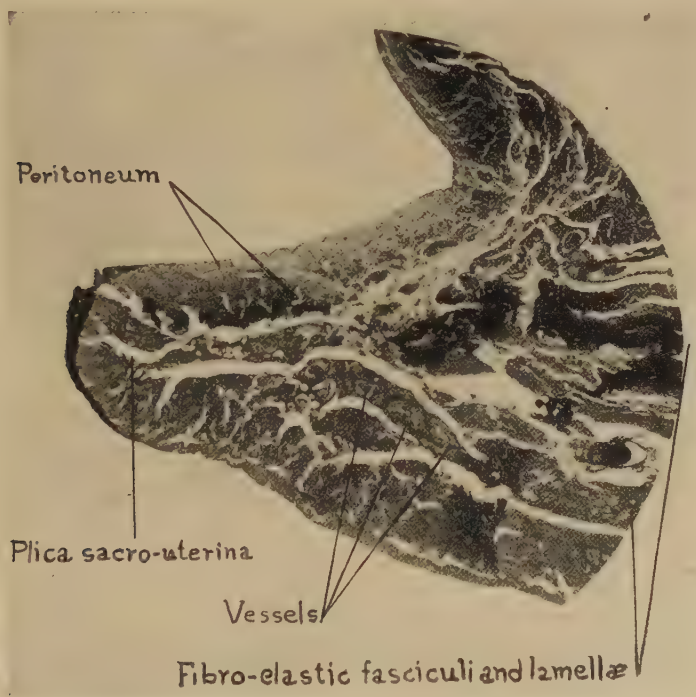

Fig. 11 Photomicrograph of a transverse section of recto-uterine fold at middle of anterior third, of a woman 35 years old. × 50, oc. 2; obj. A.

woman 35 years old. The section is through the anterior third of the fold and includes the vaginal vault. The stratum fibrosum of the peritoneum is thickened and dense, the muscular fasciculi are abundant within it.

The inner face of the dense fibrous layer shows a distinct tendency to break up into segments or divisions and most of them appear to be directly continuous with the fibro-elastic fasciculi or lamellae which sweep downward out of the fold to become part and parcel with the general fibro-elastic and perivascular network. Beneath the peritoneum therefore, the fibro-elastic

Fig. 12 Photomicrograph, transverse section of right recto-uterine fold in anterior part of middle third, of a child 10 years old. × 30, oc. 4; obj. A^2 (Zeiss).

tissue is dense and rich in blood vessels, lymph vessels and nerves. These fibro-elastic fasciculi and lamellae are parts of the plico-vaginal and sacro-uterine ligaments. The plico-vaginal constituents end in the inner surface of the thickened peritoneum, and are the fibers which caused the dimpling in of the peritoneal surface of the fold in the experiments reported above.

2. Child 10 years old. In sections (fig. 12) made at the middle of the sacro-uterine folds the peritoneum is thickened as usual and small fasciculi of muscle fibers are scattered sparsely through the slightly dense stratum fibrosum. On the border line between the latter and the subperitoneal tissue there is an aggregation of numerous large muscular fasciculi, small vessels and nerves. These fasciculi are surrounded by rather loose fibro-elastic tissue, but the general character of it is such that it can be associated with the peritoneum, rather than with the sup-peritoneal tissue. In all probability, as growth continued, a

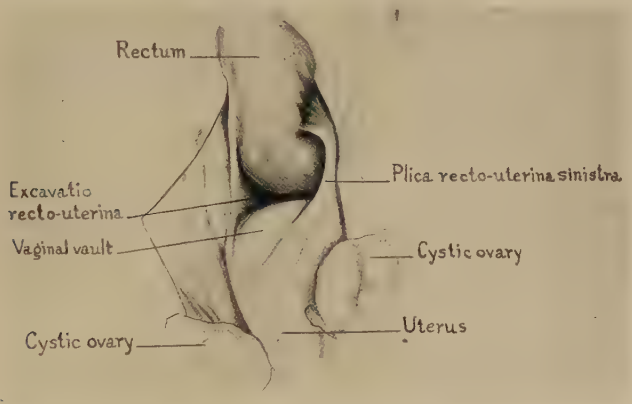

Fig. 13 Drawing showing the female pelvic viscera in an infant 40 days old. The uterus has been drawn forward. Made from the specimen studied.

greater condensation would take place and these elements would become more closely bound to the peritoneum. The sections are from behind the plico-vaginal ligament, and there are no fibers sweeping downward which could be taken for it. It is possible that a part of the above mentioned muscular fasciculi are those that accompany the sacro-uterine ligament.

3. Infant 40 days old. Figure 13 is a drawing of the pelvic viscera of an infant 40 days old. The specimen was cut in serial transverse sections. The left sacro-uterine fold was very prominent and terminated lateral and dorsal to the rectum. The right fold was much less prominent and terminated upon the lateral

wall of the rectum. The structure of the folds as regards density of the tissues, was similar to those of the adult 35 years old.

Figure 14 is a photomicrograph of a section through the middle of the right fold, the peritoneum is thickened, and in the flattened apex of the fold the intraplical fasciculi are very intimately connected to the deep surface of the stratum fibrosum;

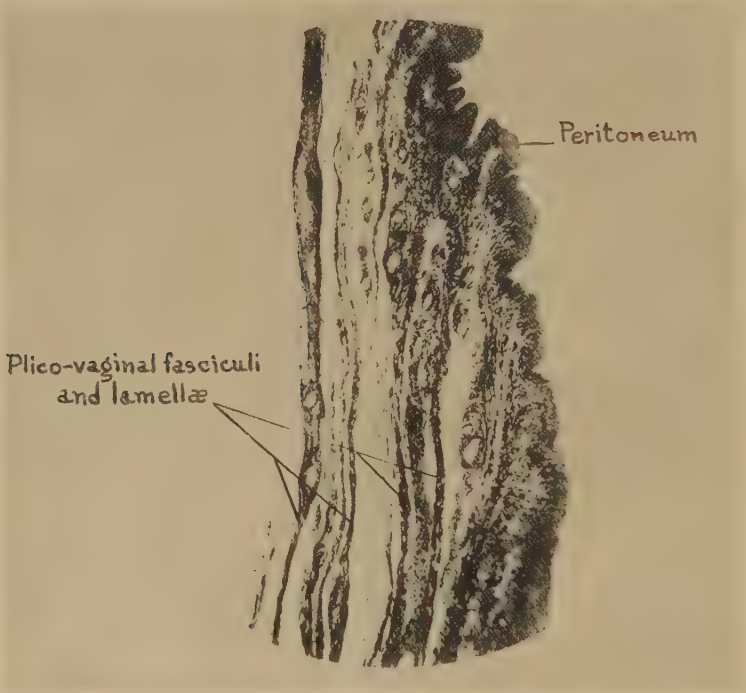

Fig. 14 Photomicrograph of a transverse section through the middle of the right recto-uterine fold, of an infant 40 days old. Note the dimpling of the peritoneal surface. × 50, oc. 4; obj. A.

in the latter there are small muscular fasciculi. From their points of insertion into the peritoneum, the fibro-elastic fasciculi stream downward lateral to the recto-uterine fossa and become continuous with the general perivascular tissue.

The photomicrograph shows the wrinkling of the peritoneal surface and the fibro-elastic fasciculi can be definitely traced downward from their attachment to the stratum fibrosum. In

both folds, these fasciculi are plico-vaginal and sacro-uterine, the former being the most evident.

The intraplical muscular fasciculi are those which in part probably accompany the sacro-uterine fibro-elastic fasciculi. To what extent these muscle bundles become associated with the peritoneum to constitute recto-uterine muscle bundles is not known.

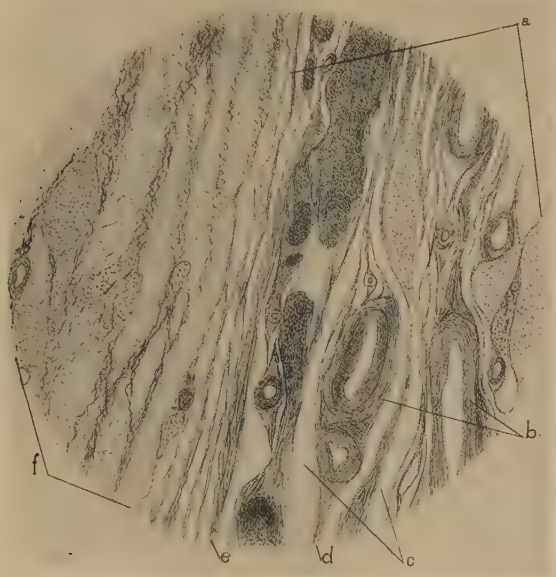

Fig. 15 Photomicrograph of a transverse section of a right plica recto-uterina at anterior third, through plico-vaginal ligament (*a*), showing perivascular (*b*) character of fibrous tissue, meshes (*c*) between the lamellae (*d*) and fasciculi (*e*) filled with delicate areolar or adipose tissue (the former has not been filled in); lateral to ligament the tissue is distinctly fibro-elastic and areolar (*f*). Infant 40 days old. × 88 diam., oc. 2; obj. A. Reduced to one-third.

Figure 15 is a drawing of the paraplical tissue below the point shown in figure 14. It shows the perivascular character of the fibro-elastic fasciculi and lamellae. The tissue shown here is a part of the plico-vaginal ligament. Particular attention should be given to the manner in which the mesh-work is formed—by division and union of fasciculi and lamellae and

how they enclose the vessels. The whole is representative of the arrangement throughout the parametrial, paravaginal and paraplical network. It has been observed that the lymphoglandulae are not as a rule enveloped by the fibro-elastic lamellae, but project into a mesh, being only attached at the hilus to a lamella, which immediately envelops the vessels entering or leaving it. At least this has been the case in a number of instances. The capsule of the gland is continuous with the lamella at the hilus.

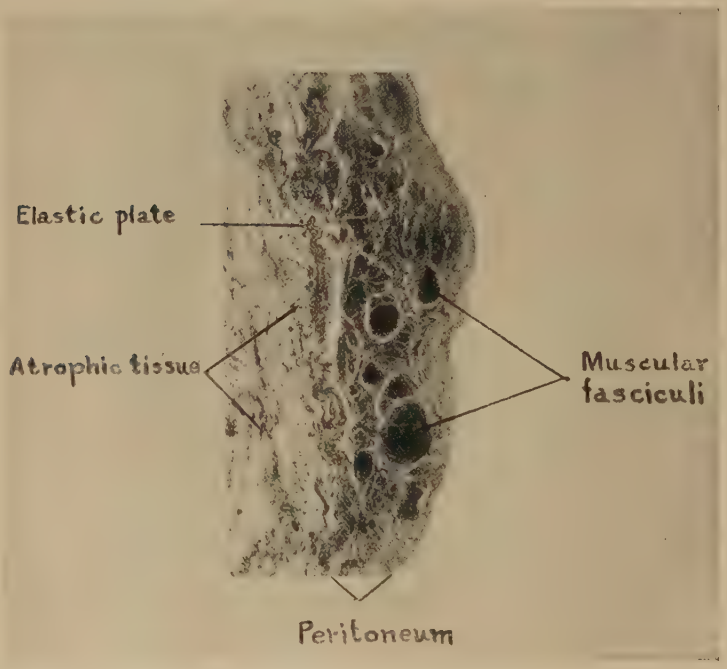

Fig. 16 Photomicrograph of a transverse section of a sacro-uterine fold at the posterior third, of a woman 65 years old. × 50, oc. 2; obj. A.

The meshes of the network are filled with delicate areolar or adipose tissue, as shown in figure 15, where a part of the meshes have not been filled in, to better demonstrate the fibro-elastic network. Lateral to the plico-vaginal fasciculi, the tissue is distinctly elastic and areolar.

4. Adult 65 years old. Figure 16 is a photomicrograph of a portion of a transverse section of a plica sacro-uterina of a woman

past the menopause. The peritoneum still remains much thickened, the bundles of the recto-uterine muscle are very distinct, and the subperitoneal fibro-elastic tissue shows distinct senile atrophy. The general looseness of the tissue is noticeable and adipose tissue is more abundant than at the other ages considered above.

Figure 17 is a drawing of a portion of the peritoneum in the section from which figure 16 was made, but more highly magnified. The muscle bundles have been drawn in heavy black to

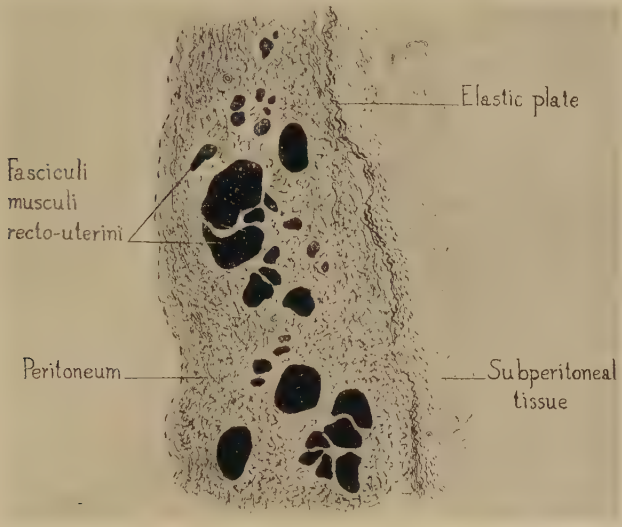

Fig. 17 Photomicrograph of part of a transverse section of plica sacro-uterina at posterior third, showing distribution of fasciculi of recto-uterine muscle, elastic plate and subperitoneal connective tissue in a woman 65 years old. × 88. Reduced to one-third.

emphasize their abundance. At the inner limit of the dense stratum fibrosum there is a distinct layer or plate of elastic tissue. Figure 18A shows this layer as brought out by Weigert's elastic tissue stain. This elastic plate lies to the inner side of the thickened fibrous stratum of the peritoneum, and becomes much thinner at the periphery of the plical area where it approaches quite close to the mesothelium; it appears to limit internally the stratum fibrosum. Whether or not this layer will be of value in

determining the relation of the recto-uterine muscle to the peritoneum remains to be seen. Figure 18B illustrates the abundance of elastic fibers in a fasciculus of the recto-uterine muscle of the same section.

5. Adult 83 years old. Figure 19 shows one of a transverse series of sections through a sacro-uterine fold of a woman 83 years old. The section has been taken from the fold at the middle of the middle third. The fibrous stratum of the peritoneum is thickened as usual, and immediately beneath the mesothelium there is a distinct layer of undulating fibers (*A*), that separates the stratum containing the muscular fasciculi from the mesothelium. The fibers of the deeper layer (*B*) are more irregular and broken, receiving the insertion of the

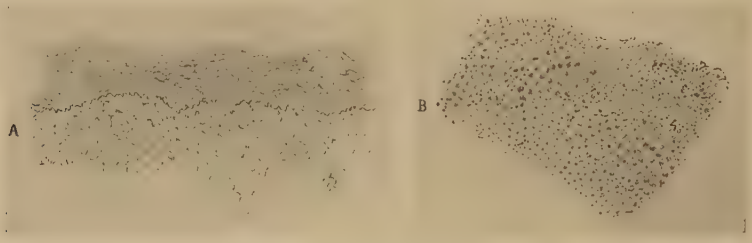

Fig. 18 A. Section of peritoneum from sacro-uterine fold of a woman 65 years old. B. Transverse section of a recto-uterine muscle, bundle, showing abundance of elastic tissue. Weigert's elastic tissue stain. × 90 diam. Camera lucida drawing. Reduced one-half.

plico-vaginal fibers which are well shown in the sections. The fibro-elastic tissue is less compact than in the infant 40 days or the woman 35 years old on account of the senile atrophy present. Weigert's elastic tissue stain also brought out a greater irregularity in the distribution of the elastic fibers. The elastic plate so well defined in figure 17 is missing here, although a very irregular line of elastic fibers is present. The stain has also brought out a greater amount of elastic tissue in the submesothelial fibrous layer that was not noticeable in the sections from which figure 16 was made. In figure 18B there is shown an abundance of elastic fibers in relation with the muscular fasciculi and it is to be noted that they are between the elastic plate

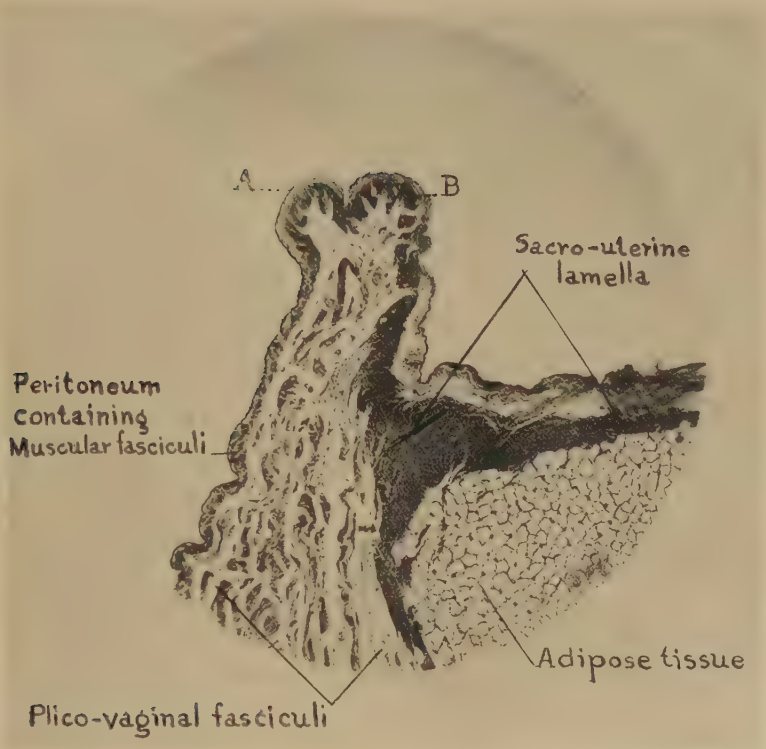

Fig. 19 Photomicrograph of a transverse section of sacro-uterine fold at middle of middle third, in a woman 83 years old. × 30, oc. 2; obj. a² (Zeiss).

and the mesothelium. Beyond the area of distribution of the fasciculi of the plico-vaginal and sacro-uterine ligaments, adipose tissue is very abundant, scattered through which is a varying but meager number of fibro-elastic lamellae that have been cut across.

VII. VARIATIONS

It is well known from observations made in the dissecting room and at autopsies, that the peritoneal surface contour of the pelvic cavity and relative size of the pelvic viscera are subject to considerable variation; at times to marked asymmetry. The bones forming the pelvic wall may vary so as to render the cavity narrow and relatively deep, or broad and relatively

shallow. The muscles may be much better developed in some individuals than in others, and the amount of fibro-elastic tissue may likewise vary.

Every gynecologist knows that the perineal body may be large and strongly constituted in some women, or feeble and scarcely recognizable. The muscles guarding the pelvic outlet are very strong and capable of affording ample support to the pelvic organs in some individuals, in others they are poorly developed and incapable of withstanding continued strain. These variations bespeak for a general habitus which may indicate a predisposition to the persistent maintenance of the norm, or an easy deviation from the same. The plicae sacro-uterinae are no exception to the rule. In certain cases they are strongly developed and very prominent and symmetrical or asymmetrical; at other times they apparently are entirely absent, or a short plica may be present on each side near the uterus. But even when visibly absent, they are potentially present, for forward traction on the uterus produces them. Or a distended rectum, by carrying the peritoneum away from the pelvic wall, will produce them or convert sacro-uterine into recto-uterine folds. The position of the rectum also influences the character of the folds. If the rectum is median in position, both folds are usually sacro-uterine; if that organ is sinistral, the corresponding fold will be recto-uterine and the opposite will be sacro-uterine and vice versa when the rectum is dextral in position. Histological examination reveals similar variations, both as regards quantity and symmetry, in the uterine supports.

VIII. EXPERIMENTS

In an anesthetized cat, with the abdomen opened and the pelvic organs exposed to view, the uterus and bladder have been observed to contract more or less intermittently as peristaltic waves passed down the rectum. Though slight, these contractions were unmistakable.

In the animal studied, the rectum happened to be strongly distended with fecal matter opposite the recto-vaginal fossa and the point of attachment of the recto-vaginal folds. The

viscus was stretched in the directions of both its primary and secondary axes. The recto-vaginal folds were large and exhibited occasional contractions, which feebly raised the vaginal vault. After the sigmoid colon had been severed and the fecal contents expelled, it was observed that the intestine slowly contracted and sank lower in the pelvis. During this descent the recto-uterine folds diminished in size and the vaginal vault sank carrying the uterus with it. The rectum was then injected to reproduce the effect on the vaginal vault through traction on the recto-vaginal folds. The rectum was clamped behind the free extremity of the vagina, and the rectum slowly distended with water. As a consequence, the rectum pulled cephalad on the folds raising the vaginal vault and carrying the uterus toward the abdominal cavity. These observations in the cat suggested, first, that the distended rectum mechanically raises the vaginal vault when its fecal contents are passing caudalward and thus prevents compression of the organs of reproduction; second, the act in all probability excites a reflex contraction in the uterus which participates in the act through the recto-uterine muscles; third, that the uterus can automatically raise itself through contraction of the recto-uterine muscles in the recto-vaginal folds.

These experiments were repeated on a cadaver of an infant 40 days old. The uterus was raised as before by traction on the right recto-uterine fold by distention of the rectum, and at the same time the partial conversion of the left sacro-uterine fold into a recto-uterine fold was accomplished. Hence the uterus can automatically raise and tilt itself ventrad in primates, or be raised mechanically by the recto-uterine folds when the rectum is distended. Or, distention of the rectum may cause reflex contractions of the uterus. When the sacro-uterine folds are present and the rectum is median in position, the uterus must act alone through a reflex. If the rectum is sufficiently distended, it can convert sacro-uterine folds into recto-uterine folds. When the uterus is raised through traction or contraction of the recto-uterine muscle, the sacro-uterine fold is tightened, the plico-vaginal ligament is pulled upward carrying the vaginal vault with it.

IX. THE MUSCULI LEVATORES UTERI

No reference has been made to the muscular tissue that passes off laterally from the uterus to be dispersed through the fibro-elastic tissue filling the subperitoneal space lateral to the uterus. Microscopical examination of the parametrial tissue shows that smooth muscle is abundant about the point of insertion of the fibro-elastic tissue into the sides of the uterine cervix, and that it diminishes in abundance as it is traced laterally and posteriorly. The fibers appear to be inserted into the perivascular tissue, the fibrous fasciculi and fasciae of the nearby muscles, but their actual termination has not been determined. Direct continuity of the recto-uterine muscles with the muscularis uteri is established. This muscular tissue extends from the uterus into the adjacent tissue at an early embryonic period. These muscles, one on each side of the uterus, enable that organ to automatically raise itself on the fibroelastic suspensorium. By their more or less intermittent contractions, they probably become one of the chief agents in aiding the venous circulation in the peri-uterine venous plexuses; the pelvic diaphragm being accessory to the act.

X. DISCUSSION

In taking up the discussion of the uterine ligaments, it is necessary to consider briefly the mechanical supports of the uterus in order to fully appreciate the part which the fibro-elastic or so-called perivascular tissue plays in the process.

The mechanical supports of the uterus will be considered in the following order:

1. The levator ani and its superior fascia.
2. The peritoneum.
3. The fibro-elastic tissue filling in the interval between the two first mentioned.

Gynecological text-books usually speak of the pelvic floor as a support of the uterus. Fothergill (15) and Cameron (13), the former preceding the latter, have described the levatores ani as forming 'a tunnel' on each side of the vagina and being attached

to it at its lower part. Cameron (13) is quite right when he states that the uterus which is above the vagina—the latter not receiving any direct support in its upper part from the muscular diaphragm—has no support from these muscles. The superior fascia of the levatores ani does not prevent the descent or ascent of the uterus. He asks why it is that the superincumbent intestines do not crowd the uterus and the vagina downward concertina-like? Cameron (13) rightly concludes that some other structures prevent this, which according to him are the 'perivascular fascia' and the blood vessels.

It is certain that the pelvic diaphragm plays a large part in supporting the pelvic viscera, and indirectly the descent of the superincumbent intestines, which when normally suspended by their mesenteries exert very moderate pressure. The normal supporting function of the pelvic diaphragm may be likened to a foundation upon which a superstructure rests, and which when it ascends or descends, carries the superstructure with it. By virtue of its contractile power and up and down movement, it also aids in preventing venous stasis within the pelvic plexuses, besides fulfilling other functions.

The superior fascia of the levatores ani steadies and aids in maintaining the cephalic extremity of the vagina and uterus in their median position, and also gives support and attachment to the parametrial fibro-elastic mesh-work. The peritoneum may be regarded as a support in the sense that it envelopes the pelvic organs as a sheet, forming lateral folds for the support of vessels and the adnexa uteri, maintaining the uterus in its normal anatomical position, and preserving this relation in its physiological excursions. Besides, as Cameron (13) states, it furnishes the superior attachment of the 'perivascular tissue.' The sacro-uterine or recto-uterine fold of the peritoneum has a varying degree of usefulness, which has already been partially stated and will be referred to again. Cameron (13) denies that these folds exert any supporting influence on the uterus, but laid great stress on the 'perivascular tissue,' which is weakest anteriorly lateral to the bladder, and between the folds of the broad ligaments; but increases in thickness as it is traced back-

ward, and is greatest in amount opposite the broad ligaments and the sacro-uterine folds. Its attachments, to quote Cameron (13) again, are as follows: "Above to the peritoneum, below to the pelvic sheaths of the levator ani and coccygeus, externally to the obturator fascia, and higher up to the periosteum of the innominate bone, while internally it blends with the connective tissues of the viscera. Its attachment to the lateral pelvic wall is rendered further secure by the fact that the parietal branches of the hypogastric vessels pierce the pelvic parietes in order to reach their respective destinations, and in doing so their sheaths blend with the surrounding bony and muscular structures." It is admitted that the "main trunks of the hypogastric vessels, in their descent on the lateral wall of the pelvis, are bound down to the latter by dense areolar tissue." Cameron (13) has somewhat over-estimated the relative size of the vessels passing to the bladder, uterus and vagina. The main vessels are large and well anchored to the lateral wall of the pelvis, and their visceral branches are supported and surrounded by the fibro-elastic tissue in part. These vessels are not a factor in the support of the uterus, and the ovarian vessels enter too high to be a support; and besides, it is to be expected that vessels which are to be put to greater or less stretching, will be more or less tortuous in their course.

The parametrial tissue contains the peri-uterine venous plexuses, which must not be kept on a strain or under continual compression. It is necessary to again call attention to the abundance of the lymphatic vascular net-work, and the numerous nerves that permeate this region. The round ligaments are of doubtful importance as uterine supports, and Fothergill (15) has pointed out that they are essentially embryonic in function. Cameron (13) has given importance to the obliterated hypogastric arteries as a pelvic support. They may act feebly. They are essentially embryonic in function. Cameron (13), after his discussion of the importance of the different pelvic supports, sums up by stating that "the perivascular fascia, plus the pelvic sheaths of the levator ani and coccygeus muscles, are the most important."

Montgomery (8) considers that the supports of the uterus are not ligaments in the ordinary sense, but consist of connective tissue, into and through which run prolongations from the uterine muscular structure, so that the organ is virtually sustained by muscular action. But he confounds the movements of the pelvic diaphragm with true intrinsic uterine activity, such as it is capable of exerting through the musculi levatores uteri. Its excursions upward and downward with 'every respiratory' movement, depends upon the action of the respiratory mechanism.

Mackenrodt (3) lays great stress on a band of connective tissue, the ligamentum tranversale colli, as of great physiological importance in maintaining the normal position of the uterus. He recognizes that the lower opening of the pelvis is closed by pelvic fascia, which sends firm bands to the cervix and vagina; that the cervix is held fast in its embryological position by ligaments, while the uterine body is kept in position by its own weight and intra-abdominal pressure—not by ligaments. Evidently this knowledge of the 'firm bands' was acquired through the dissection of embalmed material. He says that fibers coming from the pelvic fascia to the side of the cervix are to be sharply defined from the sparse connective tissue between the folds of the broad ligament. These, he states, form a band that is the chief means of holding the uterus in position. Another statement is that this band or ligementum transversale colli carries the arteria uterina in its upper part (vide fig. 20).

Ovenden (12), in her dissections, found very "little connective tissue between the layers of the broad ligament, but at the level of the cervix, however, a thick band can be felt between the two layers of the peritoneum. It is wedge-shaped in section; the apex of the wedge is directed upward and is just above the level of the point of entrance of the uterine artery. Traced to its distal attachments, this band is found to be formed from strong fibrous connective tissue, continuous with that which surrounds the pelvic blood vessels, and also that which comes through the sacro-sciatic notch. Some of the fibers appear

also to be attached to the sides of the third and fourth pieces of the sacrum."

Mackenrodt (3) considered that the ligamentum transversale colli has its central attachment at the supra-vaginal portion of the cervix. Ovenden (12) considers it inserted partly into the vaginal vault and lateral fornix, besides into the sides of the uterus for a short distance below the point of entrance of the uterine artery (vide figure 20).

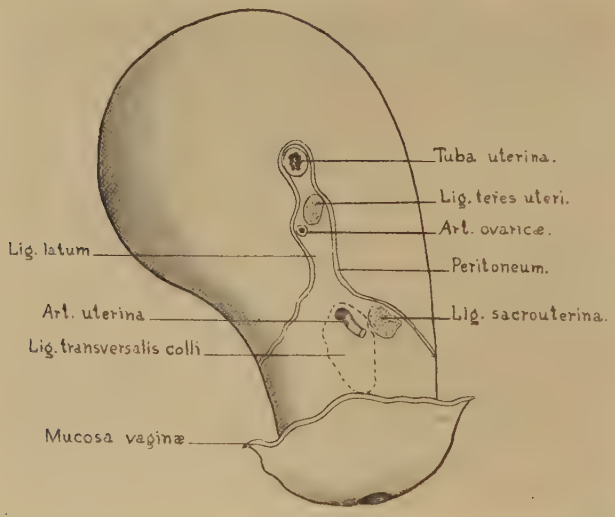

Fig. 20 Side view of uterus (as removed by vaginal hysterectomy) showing insertion of ligamentum transversale colli of Mackenrodt (after Ovenden).

These facts agree with the observations reported in the earlier part of this paper. Ovenden (12) is correct in considering that the whole mass is not inserted into the uterus, as Mackenrodt (3) asserts; and also that the sacro-uterine ligament blends with the ligamentum transversale colli near its insertion into the uterus. The plico-vaginal ligament attached to the vaginal vault becomes continuous with the sacro-uterine ligament. It is to be noted that these observations make these three ligaments continuous at their insertion into the sides of the cervix and vaginal vault.

It must be mentioned that Emmet (23) and Schauta (24) have laid emphasis on the importance of the part played by this pelvic connective tissue in maintaining the normal position of the uterus, although they did not ascribe this function to a particular band.

Specimens from the cut ends of the so-called sacro-uterine ligaments, as severed from their attachment into the sides of the uterine cervix at the time of operation for utero-vaginal prolapse in elderly women, were submitted to the writer by Dr. George B. Somers (25) for microscopical study. One ligament, evidently cut closely to the uterus, showed a great preponderance of smooth muscular tissue over the fibro-elastic; the other, much less muscular and chiefly fibro-elastic tissue. Ovenden (12) states that in microscopical sections the ligament consists largely of fibrous tissue, through which are scattered a good many bundles of smooth muscle fibers.

None of the writers have attempted to explain the marked elasticity that is inherent in the pelvic structures, not how or why the uterus can be pulled down to the introitus vulvae or to the exterior, and when released will slowly and completely return to its normal position in the pelvic cavity without further manipulation. From the experiments, dissections and observations reported in this paper, it now becomes necessary to describe the fibro-elastic suspensorium uteri, which accounts for all of the phenomena that have thus far been observed and reported.

If a square piece of thin paper be taken and folded over two or three times, cut one-half across first on one side and then on the other, when opened up it will appear as in figure 21A. Traction applied in direction of the arrows, or diagonally at the corners, will open up a mesh-work as in figure 21B. Release the paper and it will instantly return to a state of rest as before the traction was applied (fig. 21A). This paper possesses elasticity and an inherent tendency to return to a state of rest, but the phenomena are in a reverse order to that observed in the fibro-elastic mesh-work of the suspensorium uteri.

Figure 22A represents the fibro-elastic mesh-work filling the parametrial and paraplical space in a state of physiological tonus or rest (potential ligament). It is an open mesh-work,

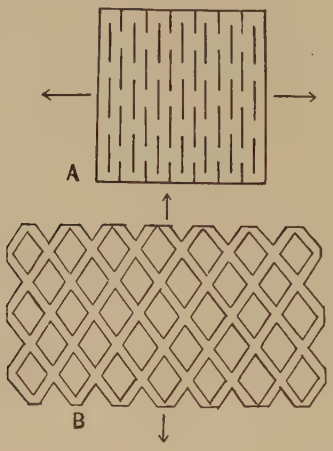

Fig. 21 A piece of tissue paper folded and cut (*A*) so as to form a mesh work (B) that possesses elasticity and an inherent tendency to return to a state of rest as in *A*, but in a reversed order to that of the fibro-elastic mesh-work of the suspensorium uteri.

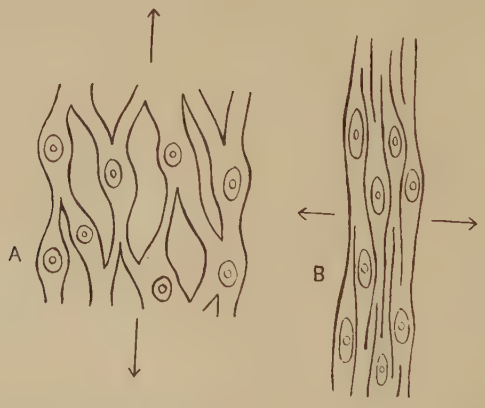

Fig. 22 Drawings illustrating the effect of traction upon fibro-elastic mesh-work. (*A*) Fibro-elastic mesh-work in state of physiological tonus or rest (potential ligament); (*B*) fibro-elastic mesh-work in state of traction (actual ligament).

the meshes of which are filled with areolar or adipose tissue. If traction is made as indicated by the arrows, the condition seen in figure 22B will result, the fasciculi and lamellae will be approximated and a transitory ligament will form. Remove the traction and by virtue of the inherent elasticity or resiliency the mesh-work returns. These simple experiments demonstrate the mechanism of the fibro-elastic suspensorium uteri.

The fibro-elastic network is like a net that has been symmetrically attached at a periphery and inserted into the two sides of a body, which is suspended by it. Traction downward on this body approximates the threads of the net which appear to diverge from the point where they are attached to it. If the body is released it is immediately carried upward until the inherent elasticity of the netting is satisfied, when a state of rest is established. The threads of the net no longer appear divergent at the sides of the body for they appear as a part of the net-work.

Such is the author's conception of the manner in which the uterus is suspended by the fibro-elastic tissue of the parametrial and paraplical space and which is aided by the pelvic diaphragm and peritoneum. From what has already been said in this paper, the full import of the argument should be clear to all.

The normal workings of the suspensory mechanism is best observed in the virgin pelvis. Various factors begin to operate at the time of puberty, which may sooner or later weaken the power of the uterine or vaginal supports. Aside from the weakening effects of parturition, with possible injury to the pelvic floor, the pernicious effects of chronic constipation and tight lacing have to be taken into account. These slowly cause the fibro-elastic tissue to give away with loss of the normal resiliency or tone.

The writer agrees with Fothergill (15) in stating that prolapsus uteri may not occur even in long standing laceration of the perineum, providing the fibro-elastic suspensorium retains its tone. In the section on variation, the writer has pointed out that the relative size and strength of parts may vary greatly in the same and different individuals. A weak pelvic floor will

not bring about prolapsus uteri if there happens to be a well developed fibro-elastic suspensorium; on the other hand, a strong pelvic floor will delay a prolapse when a weak suspensorium is present. A lacerated perineum is always a source of danger. The applied facts should be clear.

With Cameron (13), the writer suggests that an attempt must be made to restore the weakened fibro-elastic support, if success in treatment of prolapse and mal-positions of the pelvic organs is to be obtained.

XI. CONCLUSIONS

The material studied for the preparation of this paper seems to justify the following deductions and problems:

The plicae sacro-uterinae or recto-uterinae are the homologues and analogues of the plicae recto-vaginales of quadrupeds.

The musculi recto-uterini of the higher Primates are the homologues and analogues of the same in quadrupeds.

The plicae recto-uterinae and their intimately associated musculi recto-uterini are primitive, appearing in the vertebrate series before the fibro-elastic suspensorium uteri or a well developed musculus levator uteri.

The suspensorium fibro-elasticum uteri has been gradually evolved with the assumption of the erect attitude in locomotion, and is not present, or is present only in a very rudimentary way in animals which habitually assume the horizontal attitude in locomotion. If present in a rudimentary or primitive form, it is only concerned in maintaining to a greater or less extent the cephalic portion of the vagina.

In woman, and the females of the higher Primates at least, the supports of the uterus are three in number, namely:

1. The suspensorium diaphragmaticum (pelvis).
2. The suspensorium peritoneale.
3. The suspensorium fibro-elasticum.

The latter being the chief and essential support, the others being accessory.

The suspensorium fibro-elasticum consists of a fibro-elastic network supporting vessels and nerves, and contains the poten-

tial ligaments of the uterus and vagina. The meshes of the network are filled with aerolar tissue which permit the fasciculi and lamellae to move freely over each other.

The potential ligaments are the ligamentum transversale colli of Mackenrodt, ligamentum sacro-uterinum, and the ligamentum plico-vaginale, which become actual through traction on the uterus and vaginal vault.

The three above-named ligaments are directly continuous with each other at the sides of the uterine cervix and vaginal vault and with the general fibro-elastic network to the periphery.

The fibro-elastic network in a state of physiological rest forms an open mesh-work and possesses an inherent tendency to return to a state of rest after traction on the uterus or vaginal vault has ceased to operate, and neutralizes or minimizes downward pressure through this same property.

The fibro-elastic network in a state of rest prevents compression of the venous and lymphatic vessels by preventing collapse of their walls. All traction upon it more or less compresses the vessels and it hence becomes an aid to the venous and lymphatic circulations.

The upward and downward movements of the suspensorium diaphragmaticum augments the action of the suspensorium fibro-elasticum in aiding the pelvic circulation, and in this way it is analogous to the thoracic diaphragm.

The suspensorium fibro-elasticum permits the uterus being depressed to the introitus vulvae. The return of the uterus to its normal position being first aided by the diaphragmatic funnel, and completed by the suspensorium fibro-elasticum.

The musculi levatores uteri are derived from the muscularis uteri and constitute a mechanism by which the uterus can automatically raise itself on the suspensorium fibro-elasticum. By its more or less rhythmical or intermittent contractions, in conjunction with the muscularis uteri, it aids the venous and lymphatic circulation in the respective peri-uterine plexuses.

The plicae sacro-uterinae or recto-uterinae, with the intimately associated musculi recto-uterini, lifts the uterine

cervix and vaginal vault upward and backward, through stimuli received from a distended upper rectum or from other sources.

Those fasciculi and lamellae of the fibro-elastic network that arise from the presacral fasciae and along a plica sacro-uterina, and which have a general trend to the vaginal fornix and uterine cervix, behind and below the point of attachment of the ligmentum transversale colli, constitute the ligamentum sacro-uterinum, potential or actual (transitory).

Those fasciculi and lamellae of the fibro-elastic network arising from the fasciae of the levator ani, obturator, or sheath of the hypogastric vessels in the lateral wall of the pelvis, and with a general trend toward, and attachment to the side of the uterine cervix below the uterine artery, and above the ligamentum sacro-uterinum, constitute the ligamentum transversale colli potential or actual (transitory).

Those fasciculi and smaller lamellae arising from the stratum fibrosum of the peritoneum of the anterior two-thirds of a plica sacro-uterinum or recto-uterinum, and inserting into the sides of the vaginal vault below the ligamentum sacro-uterinum constitute the ligamentum plico-vaginale, potential or actual (transitory).

Any weakening of the suspensorium diaphragmaticum, which will result in a falling of the pelvic floor, or when coupled with a lacerated perineum, will result sooner or later in an overstretching, and a giving way of the suspensorium fibro-elasticum, and must result in a vaginal or uterine prolapse, or malposition of the uterus, with consequent disturbance of the fibro-elastic and muscular mechanisms, which will be rendered more or less inoperable, with resulting venous stasis and increased weight of the pelvic viscera.

In conclusion, the writer desires to acknowledge his indebtedness to Prof. A. W. Meyer, for advice, and to Prof. William Ophüls and Dr. Edgar D. Downing, for the permission to examine and use material from the autopsy room; to Prof. E. C. Dickson for the preparation of the photomicrographs.

The work was begun while the author was connected with the division of anatomy.

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SPOLIA ANATOMICA, ADDENDA II

ARTHUR WILLIAM MEYER

From the Division of Anatomy of the Stanford Medical School

TWENTY-TWO FIGURES

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A CONGENITAL INTRA-CRANIAL, INTRA-DURAL ADRENAL

The cadaver containing this strange anomaly was that of a male native of Germany. The cause of death at the age of 73 years was assigned to chronic cardiac disease. Fortunately for us the body had not been autopsied. It had been received three days after death and had been preserved as is customary with us for dissection.

Messrs. Kelker and Geistweit, two of our medical students, who removed the brain in the course of their dissection called my attention a few minutes after removal of the brain, to a small body attached to the spinal portion of the left accessory nerve.

This body which was roughly cyclindrical in form lay upon and was attached to the nerve along its dorso-medial surface. It was located directly cranial to the place where the vertebral artery pierces the dura. The body and a portion of the nerve were excised by myself in the presence of these gentlemen.

Since I took the enlargement for a neŭrofibroma I did not note its vascular or other relations as I should have otherwise done. The specimen was carefully removed, however, and its remarkable preservation has surprised everyone who has examined sections microscopically. Yet the cadaver had not been embalmed until three days after death. Dissection was not begun until seven months later and the specimen not removed until nine months after receipt of the body.

Fig. 1 Intra-dural adrenal, external view. Natural size. *a*, pedicles; *b*, loose outer capsule.

The specimen which is roughly cylindrical and measures 1.5 by 0.8 cm. is represented in natural size in figure 1. Upon inspection it is evident that the corpus proprium is surrounded by a loose capsule which bulges here and there and very evidently contains blood and pigment. The stalks which leave either pole of the specimen look somewhat like blood vessels but feel rather firm and cord-like.

Upon transverse section at its midpoint, it is seen that a very symmetrical white cylindrical body with rounded ends is surrounded by a scarcely discernible capsule and contained in a very loose outer envelope. The latter contains some blood in its looser portion only, for it is closely apposed to and seems to fuse with the capsula propria in the other half of its perimeter. It is this outer capsule which gives the specimen the peculiar irregular outline seen in figure 1.

The consistency of the specimen as well as its color made one think of the cerebral cortex. Under low magnification the cross-

section is slightly oval in form. The main portion of the section is composed of a fairly uniformly-constituted, slightly-granular mass with radial striations as represented in figure 2. The connective tissue capsule which varies greatly in thickness is quite closely applied to the contained tissue. Over that half of the perimeter where the outer capsule is thinnest the outer portion of the latter is reflected and forms a thick folded cushion of connective tissue which contains fat and a mass of blood. In the space between this outer reflected portion of connective

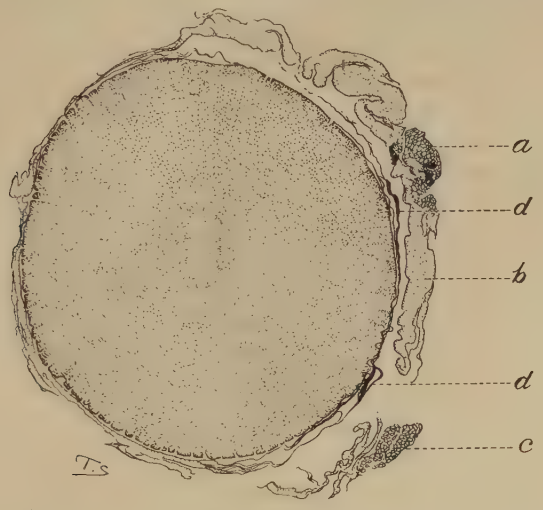


Fig. 2 Intra-dural adrenal. Cross sections under low magnification. *a*, fat; *b*, connective tissue; *c*, blood; *d*, muscle.

tissue and the inner portion of the capsula propria there is a large space which seems to contain some blood.

Under higher magnification the nature of the specimen at once becomes evident for very characteristic glomerular and fascicular zones can be recognized instantly. The former although very narrow, is very characteristic in many places. The latter is relatively longer than in human adrenals and shows a far better radial arrangement. In fact both these zones in this specimen remind one strongly of the appearance of cross-sections of the adrenal of the dog. The reticular zone is composed of a

solid mass of cells near the center of which an irregular circle of somewhat darker cells is seen as indicated by the shading in figure 2. Although these darker cells are not equally abundant in all sections of the portions cut serially, they remind one very strongly of cells from the medulla of the adrenal. The arrangement of the very evident fascicular zone is so symmetrical that the appearance of the section may justly be said to be pretty.

Under still higher magnification the cell boundaries and the nuclei are seen to be splendidly preserved in many areas as shown in figure 3. Since the walls of the capillaries are collapsed they are inconspicuous except here and there in the outer zone.

Only minor evidences of degeneration are present except in certain very small areas in the fascicular zone, which are composed of small masses of granules which stain deeply with hematoxylin. The central portion of the sections in some portions of the specimen, contains a few small clefts which do not look as though they resulted from post mortem changes or shrinkage. The relatively thin and loosely applied connective tissue capsule sends fine septa into the glomerular zone from its inner looser portion. Its outer looser portion also contains fat and unites with masses of extra-capsular connective tissue which contain fat, blood vessels and also some relatively large and many small masses of chromaffine cells. These irregularly-formed and irregularly-distributed cell masses stain deeply with chrome salts and in many places are arranged indistinctly curved cords. Since some space is left between these cords of cells the structure of the carotid gland is simulated quite closely in these areas, a small portion of which is shown in figure 4. Large and small very definitely circumscribed ovoid masses of chromaffine cells are also contained in the capsula propria. In these masses the cells are not so definitely arranged into cords however. One of these chromaffine bodies is so large that it has indented the glomerular zone beneath it as shown in figure 5. Chromaffine cell groups and fat are also found in the capsular extensions on both ends of the specimen, and on one end a great deal of pigment was found scattered about as fine gran-

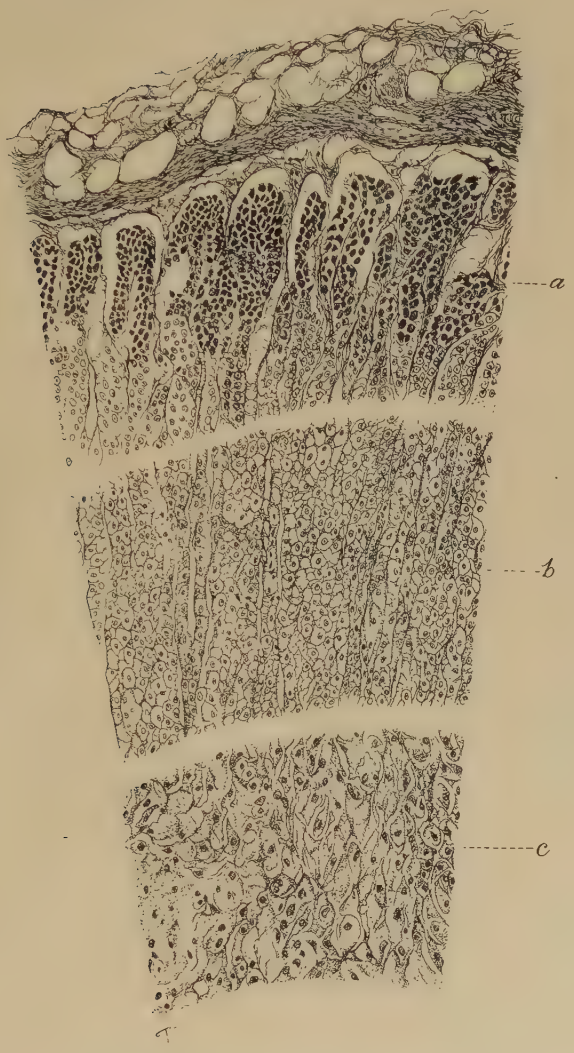
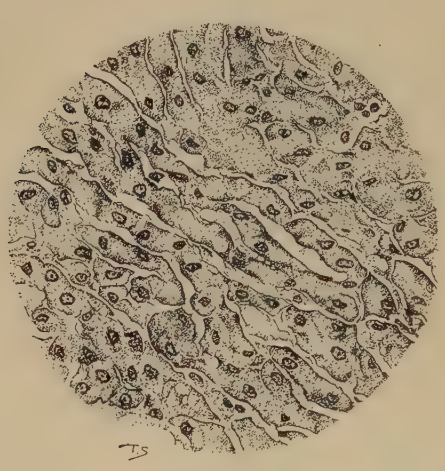


Fig. 3 Portions of the glomerular, fascicular and reticular zones and medulla. × 475.

ules or as larger masses in the connective tissue which formed the extremity. It was this end which contained only a very small group of chromaffine cells in the portion examined in serial sections. Free erythrocytes were also found in this por-

tion which nevertheless was relatively non-vascular and the connective tissue of which was not so well-preserved. Considerable areas of degenerated blood were also contained in it besides a small oval body with a thin fibrous capsule, composed of granular material containing a small number of degenerated cells of various kinds, the identity or origin of which could not be determined.

But more surprising than all of these constituents is the presence of a good-sized bundle of striped mucles muscle in the external surface of the outer portion of the reduplicated capsule.



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5

Fig. 4 Chromaffine cell masses from outer capsule. × 750.
Fig. 5 Relation of large intra-capsular chromaffine body to the adrenal.

Until the direct connection with and indeed the inclusion in the reflexion of the capsula propria, of this muscle mass had been conclusively established by following the serial sections I was inclined to regard it as an accidental inclusion in spite of the suggestive staining reactions of the strand of connective tissue with which the portions first seen were so intimately associated. These muscle fibers are so well-preserved that the transverse striations are very plainly visible in some of them. Their location is indicated at *c* in figure 2. Strands of the spinal portions

of the accessory nerve are also contained in the capsule which also contains very wide exceedingly thin-walled vessels and a good deal of fat. It is very well-preserved except in certain small areas.

The structure of this specimen and of the surrounding tissues make it very evident that it is not metastatic in origin. Not the least indication of malignancy can be seen anywhere and the only possible explanation of its presence here, it seems to me, is that a small mass of early embryonic mesnechyme was in some way included in the dura. This mesenchyme must then have differentiated into all the constituents of the adrenal, into chromaffine bodies, striated muscle, connective tissue and fat, the presence of which tissues prompts one to put the specimen among teratomata.

Various writers on pathological anatomy seem to be agreed that the so-called primary hypernephromata occur only in the abdominal cavity. It is said that they are found but rarely in the pelvis; that they occur mainly in the kidneys but rarely also in the liver, ovary, testes, ureter and the broad ligaments of the uterus. Upon the advent of malignancy these aberrant adrenals may, to be sure, metastasize as any other malignant growth to any part of the body. None of the writers consulted have referred to or have themselves described anything at all comparable to what is here reported, however, and were it not for the fact that this supernumerary adrenal is accompanied by striped muscle one might, in spite of the chronological difficulties even, be inclined to consider the possibility of later transportation or even of the migration of specific cell masses which then formed the various complexes. But its location on the spinal portion of the accessory nerve between arachnoid and dura, together with the peculiar vascular relations which it undoubtedly must have had with the meningeal vessels, alone make such a supposition quite untenable. Such a supposition would also imply the transportation of all these various cell islands at least in part by the cerebro-spinal fluid, to this peculiar location.

The very small amount of medulla within the specimen with restriction of the sympathetic elements almost wholly to the aberrant and extra and intra-capsular isolated chromaffine bodies is remarkable however, especially in that location. From the appearance of the specimen one gets the impression that although the sympathetic elements attempted to penetrate the cortical mass they only succeeded in reaching the capsule and the surrounding connective tissue leaving the corpus proprium overwhelmingly epithelioid.

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THE RELATION OF SKELETAL TO BODY WEIGHT IN THE ADULT GUINEA PIG

From computations based on statistics given by Donaldson ('15) in table 53 the weight of the dried skeleton forms 1.94 per cent of the body weight in the new born, 4.38 per cent in the half grown and 4.09 per cent in the adult rat. Waldeyer ('10) gave the weight of the skeleton of two women of 40 years as 3.306 kg. and 3.585 kg. and that of a centenarian of 102 years as 1.185 kg. Although the body weights are not given he weights given for these three fat-free skeletons indicates that they formed from 3 to 6 per cent of the normal average body weight. From the accompanying table it is seen that the skeleton of the adult guinea pig forms a somewhat smaller percentage of the body weight, than that of man but somewhat less than that of the rat. One would I think, expect his from a mere comparison of the body forms of the rat and guinea pig.

Since only ten guinea pigs were used for this determination the percentages obtained can, to be sure, not be regarded as being so near the actual for the guinea pig, as are those of Donaldson for the rat. Nevertheless with three exceptions, the percentages obtained agree very well indeed, thus reducing the probable error. Number 26 was not pregnant and hence less fat. Pig No. 35 was in the early and pig No. 20 in the late stages of pregnancy. Hence the divergences noted in these cases may probably be accounted for by these things. Similar differences are also found in Donaldson's large series and could, to be sure, be accounted for very easily by varying conditions of nutrition alone.

All animals in this series of ten pigs were pregnant, save No. 26. The weight of the uterine contents was, however, always subtracted from the total body weight before percentages were calculated.

The skeletons were cleaned by heating the fresh carcass in a 1 per cent solution of gold dust for five to seven hours. They were then dried for one week in a thermostat at a temperature of 54 to 55°C. after which the first weighing was done. Next they were placed in benzine for six to seven days in order to extract the fat and dried at room temperature for a week. The second weighing was then done. The treatment was exactly the same in several groups which were handled together.

From the percentages representing the relative weight before and after treatment with benzine it is seen that the reduction in weight amounts to 4 to 5 per cent of the weight of the cleaned, air-dried skeleton. This is a remarkably low amount of fat when compared with the results given for other animals.

NO. OF PIG	DURATION OF PREGNANCY	BODY WEIGHT	DRY SKELETON	PERCENTAGE	SKELETON DEPRIVED OF FAT	PERCENTAGE
20	64	751.30	30.400	4.04	29.555	3.93
21	51	722.00	25.550	3.53	24.420	3.38
22	48	813.50	29.700	3.65	28.400	3.49
23	44	844.20	28.520	3.37	28.097	3.32
26	0	751.00	33.300	4.43	32.870	4.39
27	33	943.85	31.520	3.34	30.737	3.25
28	31	866.56	30.780	3.55	29.172	3.36
29	29	692.66	24.730	3.57	23.420	3.36
31	25	901.50	30.790	3.41	29.875	3.31
35	15	688.30	28.840	4.19	27.770	4.03

LYMPHOID NODULES IN THE LIVER OF ALUCO PRATINCOLA

In a specimen of the common barn owl—Aluco pratincola—lymphoid nodules of varying though small, size were found distributed at random throughout portions of the liver. The latter which looked wholly normal had been removed from a young owl about six months old. It contained no signs of inflammation or degeneration, either macro- or microscopically, and the young owl which had been under observation for some months had never shown any signs of illness.

These accumulations of lymphocytes mixed with erythrocytes were of microscopic size, the largest measuring only a small fraction of a millimeter. Most of them were irregular in form and included extensions of the parenchyma of the liver into them Not rarely, however, one of the smaller follicles was surrounded by a very thin but distinct layer of connective tissue which could be regarded as a capsule. Those observed contained neither germinal centers nor an evident reticulum.

The lymphocytes were crowded together and included relatively few erythrocytes. When small collections of erythrocytes were present they were usually segregated fairly well from the lymphocytes. The nuclei of the latter were not pyknotic but vesicular, as is the case within the lymph follicles of lymph nodes. No polymorphonuclear leŭcocytes or giant cells were seen in these follicles and no evidence of any phagocytosis was observed. The lymphocytes were not arranged in cords but were scattered about miscellaneously and no lymph vessels or sinuses were observed. Comparatively large blood vessels were, however, not infrequently seen near these nodules, penetrating them, and forming sinusoids within them. The general appearance is indicated in figure 6.

LYMPHOID NODES IN STRIGIDAE

From an examination of 31 species including 14 families Jolly ('10) concluded that, among birds, lymph nodes are found only in some members of the group 'Lamellirostres' of the family Anatidae. Jolly failed to find them in Branta bernicla L. for example. Thirteen species of 'Lamellirostres,' all of which fall in the family Anatidae and one in the Phoenicopteridae were examined by Jolly. Ten in the former and one in the latter, viz., Phoenicopterus roseus Pall, contained lymph nodes. Of the other families examined none were found to possess lymph nodes. These families included: Alcidae, 1 specimen; Colymbidae, 2; Laridae, 1; Ardeidae, 2; Otididae, 1; Tetraonidae, 4; Columbidae, 1; Picidae, 1; Corvidae, 1; Alaudidae, 1; Sturnidae, 1; Fringilidae, 1; Strigidae, 1; Polyborniae, 1.

The inclusion of a specimen of Strix flammea L. in this list attracted my attention because I had incidentally in the course of other investigations, come upon what I took for lymph nodes, in a specimen of Aluco pratincola (Strix pratincola) the common barn owl. These nodes were found in the abdominal and thoracic cavities and were taken for lymph nodes when removed. Unfortunately, however, since they were incidentally removed and since two other owls were then available, the exact loca-

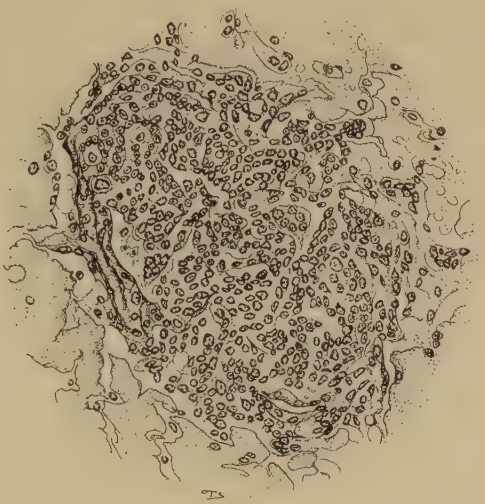

Fig. 6 Lymphoid nodule from the liver of Aluco pratincola. The surrounding hepatic parenchyma is merely indicated. × 475.

tion of these nodes was not specially noted at the time of removal. The specimens were fixed in Zenker's solution, however, and were found to be unmistakably lymphoid in structure.

These nodes were cylindrical in form, 2 by 1 mm. in size and pale grey in color. This color may be accounted for by the fact stated by Jolly, that the sinuses of the lymph nodes of birds seldom contain enough blood to make the nodes look pink. Under low magnification no germinal centers or lymph sinuses were evident, although the parenchyma was an open one. In spite of the pale grey color of the gross specimens and the ab-

sence of blood-filled sinuses the stained mounted sections seen under low magnification suggested hemal nodes. Upon closer examination it was seen however that this was due to the presence of an unusually large number of large pink hyaline looking cells (fig. 7) which suggested erythrophages. These cells were scattered throughout the section of the node and contained vesicular nuclei which were generally located near the periphery. Although not contained in sinuses they are apparently somewhat comparable to those described by Jolly in the sinuses of lymph

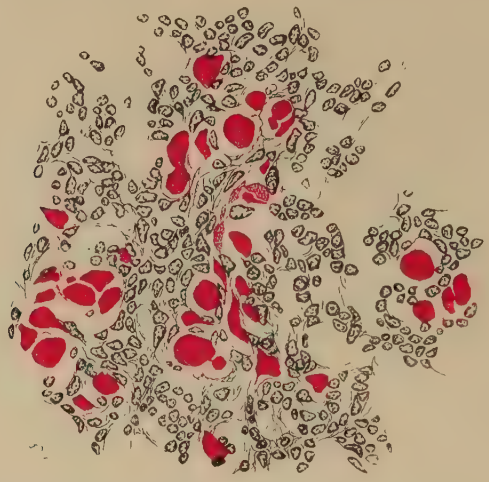

Fig. 7 Portion of a lymphoid nodule showing distribution of polykaryocytes and large acidophile cells. × 750. *a*, capillary.

nodes of birds, as containing cellular débris within their protoplasm. The débris according to Jolly was composed of remnants of nuclei, erythrocytes and blood pigment all of which were "transformed into globular masses taking an acidophile stain."

Rarely polykaryocytes of the above type were also seen. These were extremely large and the protoplasm not infrequently contained what seemed to be remnants of nuclei. Sometimes larger, irregular masses which apparently had been formed by the coalescence of polykaryocytes were also found. These

masses were far larger than any I had ever encountered before in any lymphatic tissues examined (fig. 8). Since distinctly or indistinctly outlined erythrocytes were, however, never seen within these cells one is lead to doubt whether these large cells were really erythrophages for the nuclei of the erythrocytes unless destroyed before ingestion or extremely rapidly after that, should have been visible in some cells at least.

Fig. 8. Portion of a lymphoid nodule. × 515. *a*, capillary.

CAPILLARY CAPSULES IN THE SPLEEN OF ALUCO PRATINCOLA

During the examination of sections of the spleen of the owl, under low magnification, small groups and isolated syncytial-like masses with a small central opening with a circular or more or less elongated form especially attracted attention. These capsules characteristic of birds gave the impression that the spleen was studded with extremely large multinucleated giant cells, were always contained in the areas of lymphocytes and were absent in those areas of the spleen which were largely or almost wholly composed of erythrocytes. Upon higher magnification it was found that the small central openings contained in these masses were fine vascular capillaries which were

surrounded by a capsule of an epithelioid syncytium which was from four to six times as thick as the caliber of the capillary. Whenever some of these capsules were cut more or less obliquely and also when adjacent capsules coalesced, large irregular masses with smooth outlines resulted, but whenever the capsules were cut transversely the small capillary was usually centrally located in the section. Not rarely two small capillaries one of

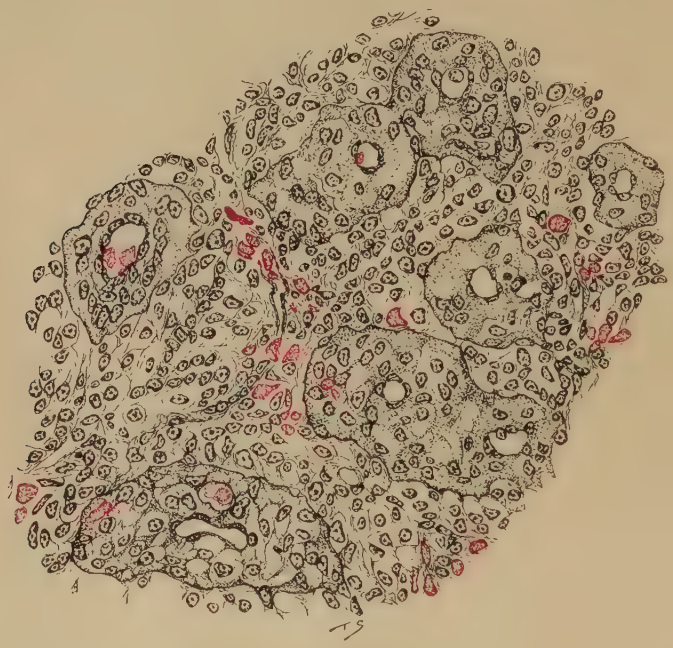

Fig. 9 A group of capillary capsules of the spleen of Aluco pratincola. × 750.

which was eccentrically placed were contained in such a cross section. Some of these capsules lay directly beneath the splenic capsule or even caused it to bulge. They were always well-defined and sometimes surrounded the capillary at the point of branching. Because of this fact and because of the consequent fusion of such adjacent and other capsules and perhaps also for other reasons, the size of these capsules varied considerably although there was but little variation in the caliber of the enclosed capillaries (figs. 9 and 10).

Not infrequently two fairly concentric circles of nuclei were evident in cross section of these capsules. The outer circle lay directly beneath the periphery and the inner directly around the capillary. The latter was, of course, formed by the nuclei of the endothelial cells of the capillary and except for a slightly smaller size and a somewhat more oval form the nuclei forming the inner and outer circles seemed to be identical in appearance. They were always vesicular and contained a number of distinct chromatin granules. Sometimes they were distributed irregularly throughout the cross-section of the capsules. The inter-nuclear protoplasm stained pink with eosin and was non-granular. Cell boundaries were never recognizable and no cells except rarely a few isolated erythrocytes or fragments of such were seen in the syncytium of the capsules.

In some cases the capsules instead of being composed of an epithelioid syncytium were composed of such merely along a narrow margin of their periphery and in the region immediately surrounding the capillary. The intervening space is partly filled with a rarefied tissue the individual nuclei of which are surrounded by small more or less confluent, amounts of protoplasm giving these portions the appearance of mesenchyme.

Aside from these capsules the entire absence of Malpighian corpuscles attracted attention. Not a single corpuscle was found in the sections examined and the only substitute for them were these large circum-capillarial capsules surrounded by lymphocytes. Since as many as a dozen of these capsules often lay quite closely together forming rather large pink-staining masses which were surrounded by blue-staining lymphocytes they were very conspicuous. The portions of the spleen examined contained few large sinuses, a considerable quantity of erythrocytes, few trabeculae and had a thin capsule.

Kyber ('70) found the capillary capsules in the dog to be 0.05 mm. wide and 0.15 mm. long. According to Kyber, Fenenko also described capillary capsules first so-named by Schweigger-Seidel, ('62) who worked on the pig. They were discovered by Billroth, ('57) in birds and described by Müller ('65) in frogs,

reptiles and birds. Bannwart ('93) found them in the cat and Kultschitzky ('95) in Putorius vulgaris.

Kyber thinks that they are formed by local distensions (Auftreibungen) of the adventitia of the arteries, which then enclose the splenic parenchyma in the form of a thin sheath of the ends of the terminal arteries. Kyber states that previously to his publication they had been described in the pig, dog, cat and hedgehog only, but Bannwart states that Müller found them indicated in the mole and rabbit also and found them in capsules but non-striated muscle and polymorphonuclear leucocytes were never noticed. The very large size of the capsules in the owl's spleen as well as the large caliber of the capillary are evident by a mere reference to the figures.

PHAGOCYTOSIS IN THE LIVER OF FELIS DOMESTICA

The animal from which this specimen was obtained was an old but well-nourished pregnant female. The four foetuses and one abnormal ovum were about 3 cm. long. Although the cat had been handled very carefully and was killed in a gas chamber the abdomen was found full of fresh blood. Upon inspection of the viscera it was found that blood was oozing from the whole of the ventral surface of the liver and upon gently wiping the surface with a wad of cotton it was evident that the oozing came from small dark discrete points, the central veins. A little firmer wiping abraded the thin capsule and exposed the parenchyma of the liver. The latter was very friable and yellow but the other viscera appeared macroscopically normal except that the ovaries were cystic.

Upon microscopic examination the capillaries of the liver which contained but little blood, were found to contain numerous erythrophages as shown in figure 11. These cells which had a distinct cell membrane and a flattened crescentic nucleus which had been pressed against the cell wall, were about the size of the cells of the hepatic parenchyma. They were engorged with erythrocytes the outlines of which were still plainly visible in many of them. No phagocytosis was present in the spleen, sections of which showed a rather rarefied parenchyma.

Fig. 10 Two adjacent partly fused capsules containing a branching capillary. × 720.

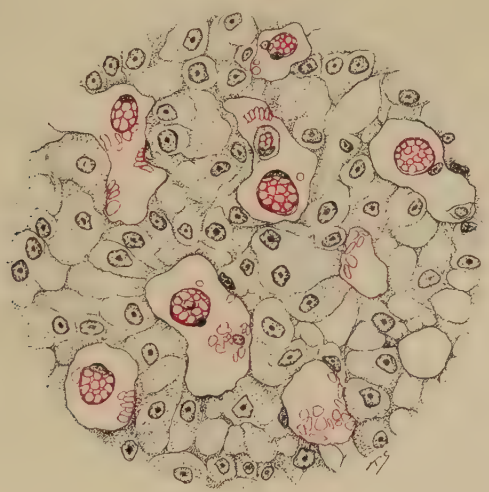

Fig. 11 Phagocytosis in the liver of a cat. × 1050.

The kidneys showed a few old lesions but nothing else of consequence.

In spite of the very active phagocytosis of erythrocytes in the capillaries of the liver of this cat I found no indication whatever of phagocytic activity on the part of the hepatic parenchyma itself as observed by Browicz ('99). Nor did I see instances of

phagocytic activity on the part of the attached endothelial cells such as was observed by Heinz ('01). Nevertheless, the character of the phagocytic cells suggests an endothelial origin and to that extent confirms Kupffers ('99) conception of the phagocytic capacities of the endothelium of the liver. The entire absence of phagocytosis in the spleen of this cat would also seem to preclude an extra-hepatic origin of the erythrophages in this case.

Hemorrhage into the abdominal cavity and apparently always from the liver, was also observed not infrequently in other animals killed by the use of illuminating gas. Since the animals are placed in a roomy lethal chamber and the gas turned on so slowly that death almost invariably results without a struggle, I can only suggest that for some reason unknown to me, extreme congestion of the liver with a possible change in permeability of the capillary and capsular walls must occur during death by the use of illuminating gas.

THE ARCHITECTURE OF THE PROXIMAL EXTREMITY OF THE HUMERUS

While scrutinizing the nature and the extent of the epiphyseal line in mature bones my attention was attracted to small areas adjacent to the epiphyseal line, in which the spongiosa is not infrequently absent. Often when not completely absent it is rarefied. These areas which were observed in the humerus, recalled Wards triangle and the similar rarefied areas in the spongiosa of the bodies of the vertebra and of the os calcis. Closer examination of a series of humeri showed that rarefaction or absence of the spongiosa were correlated with the retention of the epiphyseal line or plate. These absorption areas were always located in the lateral region of the shaft directly under the greater tuberosity a region in which the epiphyseal plate is best preserved. It is interesting and significant that a similar although not a corresponding absorption of the spongiosa can also be rarely seen near the epiphyseal line of the great tochanter of the femur.

As shown in figure 12 these absorption areas occur on both sides of the epiphyseal plate and their size and the completeness of the absorption of the spongiosa, seem to vary directly with the completeness and strength of the epiphyseal plates.

Whenever a part or the whole of the epiphyseal line was marked by a partial or complete bony septum or by two parallel thinner septa, the areas devoid of spongiosa were found the largest. Sometimes, however, there was only a partial absence or a rarefaction of the spongiosa and as shown in figure 12 when no epiphyseal line was evident there was no indication of absorption. If on the other hand the epiphyseal line was absent altogether no absorption areas were found. This relationship would seem to suggest that a strong epiphyseal plate relieves the spongiosa about it of most even if not of all, of the strains and stresses and thus causes its atrophy and rarefaction and finally its complete absorption. This conclusion would seem to be supported by the occurrence of all manner of transitions between a perfectly normal spongiosa and complete absorption and it is significant that the trabeculae of the spongiosa which are still preserved extend mainly at right angles to the epiphyseal plates thus acting as braces to relieve lateral strains.

That the presence of such remnants of the epiphyseal plates has resulted in the absorption of the spongiosa is also suggested by the specimen of the humerus shown in figure 13. This specimen shows a large absorption area in the spongiosa, directly beneath the site of the great tuberosity, in which the spongiosa has completely disappeared probably in consequence of the disuse following articular disease. This humerus came from an extremity in which the long head of the biceps and the compacta in the region of the tuberosities had been completely destroyed by arthritis. There is no evidence of pathological processes within the spongiosa, however, Although the compacta of the humeral head shows some erosion it is also very evidently atrophic. Since the spongiosa around the empty area shows nothing suggestive of a pathological process it seems not unlikely that in this case absorption of the spongiosa may at least have been hastened by, even if not directly caused by, a lessened use during disease.

Fig. 12 Absorption near epiphyseal plates in three humeri and a great trochanter of the femur.

SERIAL TRANSVERSE BONY MEDULLARY SEPTA OF THE TIBIA

von Recklinhausen ('93) described transverse partitions as not infrequently occurring in the broad and thick portions of the diaphysis of long bones where the compacta is thin. He states that as many as twelve such partitions may be present in the lower end of the femur when the latter seems inflated (aufgetrieben) when viewed from the outside. According to von Recklinghausen transverse septa may also occur anywhere in the tibia and rarely also in the fibula and ulna, but never in the

Fig. 13 Absorption area under the greater tuberosity in a case of chronic articular disease.

humerus and in the upper femoral regions. They were also found regularly in the bones mentioned when multiple exostoses were present, in femora with a short neck and, in general, in bones of light weight possessing the loose texture characteristic of osteomalacia. They were also found in bones from females below ten to twenty years and also in the upper extremity of the tibia of a twelve year old dog. von Recklinghausen emphasized that these septa may be distributed at regular intervals and may be found even in the middle of the shaft where the compacta is thickest. He concluded that they are remnants of the solid

portions of the bone which originally formed the epiphyseal plates of the growing bone, and have no mechanical significance.

The occurrence of isolated complete, partial or fenestrated transverse septa in the shafts of certain long bones, is of course very common, but the presence of a series of parallel septa at comparatively short intervals as shown in figure 14 is rare.

Fig. 14 Tibia with transverse septa.

This specimen also deserves special comment because of the rarefaction and the nature of the spongiosa between the septa. The atrophy of the spongiosa near and between the septa can, it seems to me, be attributed to the presence of the transverse septa. Although none of these five partitions are complete and although all of them are fenestrated, rarefaction of the spongiosa is especially evident near them. All of these septa are found in the dorsal portion of the proximal extremity

of the tibia and three of the five are much stronger than the other two which are composed merely of a framework of spongiosa. The spongiosa between the septa is represented by a few very fine strands only and these extend mainly in a ventral direction at right angles to the septa.

Nothing observed in this specimen militates against von Recklinghausen's belief that such septa are remnants of former epiphyseal plates, but transverse septa located at or very near the midpoint of the shaft of a long bone could hardly be regarded as having such an origin. Moreover, the rarefied spongiosa in the proximity of the septa and also between them, indicates quite clearly that such septa are not necessarily or even very probably, wholly without mechanical significance as von Recklinghausen suggested.

INIAL FOSSAE AND CANALS

The skull shown in figure 15 I owe to the generosity of one of our former students Mr. Benjamin R. Hewitt. It was taken from an Indian Mound near San Jose, California, and as shown is markedly deformed. Although the deformation is marked it is nevertheless quite symmetrical and shows itself mainly by a decided flattening in the occipital region and of the vertex. The forehead is an extremely receding one, a gentle depression marks the glabella and the supra-supraciliary regions. The skull is decidedly prognathous and the norma frontalis which forms an angle of approximately 40 degrees with the vertical, is roughly parallel to the occiput. The obelion is located about 3 cm. posterior to the line passing through the mastoid processes and is marked by two small pits about 3 cm. apart which lie on opposite sides of the sagittal suture and which probably represent obliterated emissary foramina. The cerebellar fossae are deep, that on the right being the deeper, as usual. The floor of the left fossa is exceedingly thin and defective, partly no doubt from post mortem decay. The portion of the occipital bone bounding this fossa is much thinner, however, being only a few millimeters thick. All the sutures are still evident on the exterior and a good-sized 'os Incae' is present. The linea nucha

Fig. 15 Indian skull with inal canal *a*, rear; *b*, side view

suprema is very evident but the linea nucha superior can not be dentified definitely. A very marked external occipital protuberance is present. This protuberance takes the form of a

torus 4.5 cm. long and somewhat over 1 cm. high at its midpoint. One centimeter above the protuberance there is found a very marked but definitely circumscribed oval pit 1.2 by 0.7 cm. deep. The canal leading from this pit is obstructed in part, by a plate of bone about 1 mm. thick the edge of which has very probably been destroyed.

On sagittal section of the skull it is seen that the canal is somewhat irregular in form being obstructed by the thin plate of bone mentioned above, on the inferior portion near its inner orifice. The latter is irregular in form and measures 7 by 7.5 mm. Since the canal is funnel shaped the outer orifice is much larger, measuring 1.8 by 0.8 cm. in the transverse and vertical diameters respectively.

The mastoid foramina are small, the parietal are obliterated but the jugular foramina are large. Hence it seems to me that one could hardly assume the presence of obstruction to the venous return and regard this canal as an enlarged occipital emissary vein. Moreover, were it to be regarded as such it would for several reasons be an extremely rare instance. The occipital emissary vein is usually small, it not infrequently pierces only one table and is often absent altogether. It is true that the canal in this skull leads partly into the sŭlcŭs for the left lateral sinus but the character of the canal itself is wholly different from the enlarged mastoid canals not infrequently seen especially in rachitic skulls as emphasized by Merkel. It is possible, to be sure, that the canal in this skull has nothing in common as to its origin, with the sulci and fossae found in this region in the other skulls. Nevertheless if it is to be regarded as an enlarged emissary canal its character can only be explained by assuming a decidedly deforming influence upon it by the forces which deformed the skull.

It is impossible to find a satisfactory embryological explanation for this peculiarity and since three other Indian skulls in a small collection of 60 possess, roughly similar depressions in exactly the same location, it is probable that these pits or defects have another origin. It is true that these defects lie in the region of the union of the interparietals with the supraoccipitals

but their character does not suggest a developmental origin. In one of the other three specimens there is a small circular depression about 3 mm. deep at the center and $1\frac{1}{2}$ cm. wide. The other two skulls merely have very irregular small depressions and a fourth shown in figure 16 has a definite larger depression directly in front of the superior nuchal line.[1]

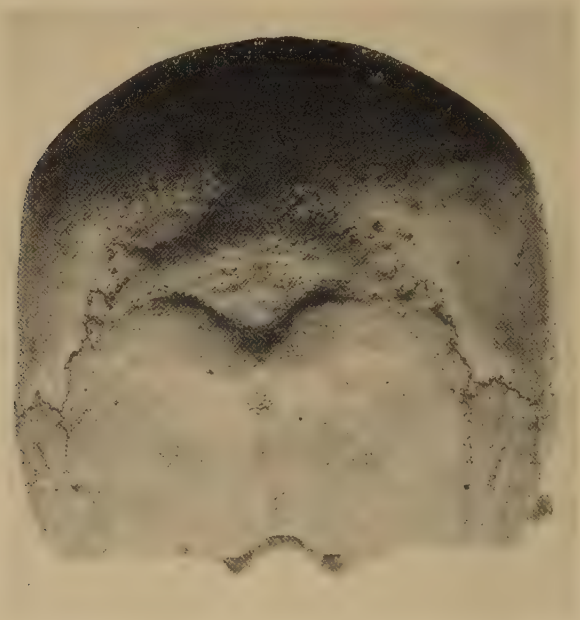

Fig. 16 Indian skull with peculiar depression

It is true that Frasseto ('02) in a purely theoretical and hypothetical discussion says that an inial fontanelle was described by Maggi ('00) and by Staŭrenghi ('99). I have examined a number of papers by these authors but have been unable to find anything in their comparative anatomical studies at all comparable to what is here described and pictured.

[1] In view of Dr. Hrdlička's large acquaintance with skeletal remains gathered in widely different parts of the world and especially with American Indian remains, I brought the accompanying illustration to his attention. My expectations were fully justified, for Dr. Hrdlička has a series of specimens with similar, even if not identical, characteristics in the Smithsonian Collection.

NOTES ON 'SENILE' ATROPHY OF THE CALVARIUM

The erratic nature of bone resorption on the calvarium in the region of the parietals and sutures must continue to impress everyone. This is particularly true since we are in the habit of attributing the differences in relative degrees of senile atrophy between the bones of the upper and lower extremities, to differences in activity. Waldeyer ('10) also had recourse to such an explanation in connection with the findings in his unique study of the skeleton of a centenarian but in the case of the peculiar concentric atrophy of the calvarium we are left without this explanation.

Voigtel (1804), Lobstein ('24), Rokitansky ('44), Virchow ('54) and Maier ('54) were among the earliest investigators who described examples of this peculiar form of atrophy. Voigtel who refers to several earlier authors pictured a specimen from Meckels collections in which the atrophic area measured 3 by 2 inches. In one of the two cases reported by Virchow the bone in the atrophic area which measured 2.5 by 1.5 inches was, only "$\frac{1}{2}$ a line thick." According to Virchow the atrophy in the regions of the tubera parietalia never extends beyond the 'linea semicircularis' the insertion of the temporal muscle always definitely limiting the area. Virchow found atrophy present in other regions of the calvarium, however, and also noted joint changes.

Maier who likewise described two specimens of calvaria reported a case of death following fracture in one individual. Maier like Virchow, emphasized the porosity of the whole calvarium, the whiteness of the atrophic and the yellow color of the preserved areas, and spoke of the presence of a peculiar reticulated appearance due to the presence of lighter stripes among the yellow. Maier, however, found that the atrophic area extended beyond the 'linae semicircularis.' In the first skull reported by Maier the bone in the region of the 'tuber parietalia' was translucent over an area as large as a 'Zwölfkreutzerstück;' that is, about 3.5 cm.; and as thin as 'Postpapier.' In the second skull the atrophic area was two inches long and one inch wide.

In reporting the case of a woman of 90 years who had suffered a fracture of the calvarium indirectly as a result of such atrophy, Humphrys ('90) also stated that "The most common parts for the extreme thinning are the parietal bones on the side of the sagittal suture, midway between it and the tubera, causing the remarkable symmetrical depressions of which many specimens exist." Humphrys also was impressed by these "changes of an opposite nature" in old age—the absorption from without and the deposit from within.

Rokitansky suggested a probable relation to lues but Virchow, Maier, Humphyrs, Ziegler, Aschoff and others all refer the atrophy to senility alone. Smith ('06) called attention to the fact that this form of atrophy is rare in European crania and stated that Humphrys found only six instances of it in European museums. According to Smith this peculiar form of atrophy is common in ancient Egyptians and never affects the parts of the calvarium covered by muscles. Smith further stated that a ring of bone 1 cm. in diameter is always left around the parietal foramina. Although out of the 70 specimens examined by him, not one was found below the age of 25 or 30 years, Smith nevertheless concluded that "It cannot be regarded as a senile change because it frequently occurs in crania where the coronal, sagittal and lambdoid sutures show no trace of closing." Although this atrophy was not found limited by sex, Smith found it present only in skulls taken from the tombs of the wealthy from the period between the fourth and nineteenth dynasties. Smith came to the conclusion that this atrophy is not congenital but is due to a continuous, slight pressure because he found, "This cranial thinning only in those people who were accustomed to wear wigs of enormous proportions and of great weight." Smith added by the way of qualification, however, that a causal relation does not necessarily exist between the two.

The first calvarium upon which I wish to comment is one with a roughly rectangular depression 3 by 5 cm. long and 2 mm. deep over the mid-frontal region. The borders of this depression are very regular and smooth and a roughly corresponding

bulging of the inner table is present but the two do not coincide exactly and cannot definitely be attributed to fracture. The portions of the coronal and practically all of the sagittal and lambdoid sutures which show on this calvarium are obliterated internally but are still evident externally.

The thickness of the calvarium varies from 4 to 9 mm. and measures 5 to 7 mm. over the depressed area. The sulci of the middle meningeal artery are not deeper than usual but the arachnoidal and lacunar depressions are unusually large and deep, some of them extending well through the outer table. Yet on the whole this calvarium is heavy and its general appearance does not suggest senility. Compared with the measurements of Anderson ('00) which it is unfortunately very difficult to utilize because they are recorded in sixty-fourths (!) of an inch, this calvarium is above the average weight. The diploe are quite well-preserved but the lamina are thick. Only the right parietal foramen is preserved.

The second specimen which is very evidently senile has a small absorption area over the sagittal suture about 2 to 3 cm. anterior to the obelion, and a similar though less pronounced area on the lateral mid-parietal regions directly medial to the temporal ridges. The coronal and lambdoid sutures show faintly on the exterior and the whole anterior vault of the skull up to the absorption area in the mid-line shows definite vascular and nerve markings. The sulci for the right supraorbital nerve extend beyond the coronal suture.

The internal surface of this calvarium is rough and shows considerable deposit. There are several exostoses in the frontal region and also deep tortuous arterial sulci. The condition of the rest of the skeleton would suggest that a marked reaction probably of syphilitic origin, was present. Although the frontal sinuses are small this calvarium measures over 1 cm. in thickness. The lamina externa and interna are very thin but the diploe thick and well preserved. The coronal and lambdoid sutures are faintly indicated externally and the right parietal foramen is well-preserved.

The third specimen is a very light calvarium in which the location of the sutures is marked by sulci. There is a very shallow and narrow sulcus over the coronal suture but the sulci over the dorsal half of the sagittal and the lambdoid sutures are deep and wide and by their nature remind one at once of the peculiar large absorption areas in the parietal bones above referred to. As shown very imperfectly by the photograph in figure 17 there are roughly-corresponding, comparatively large absorption areas in the posterior mid-parietal regions. Both

Fig. 17 Calvarium showing absorption areas

these parietal absorption areas and the central sagittal area contain small areas varying from 1 to 4 sq. cm. in which the bone is less than 0.5 mm. thick. This calvarium which is light and thin, measures 7 mm. in thickness at the lateral border of the parietal absorption areas. This is the greatest thickness found. Except for a slight roughening along the superior sagittal sulcus there is no evidence of bone deposition on its anterior. The figure formed by the sagittal and lambdoid absorption areas although T-shaped, has nothing in common with the T-scars of the dolmen skulls reported by Manouvrier ('04). Since the latter have a mechanical origin being according to Obermeier,

due to scraping for aesthetic or dedicatory purposes they have a wholly different character. The slightly pitted outer surface of this calvarium also suggests senility. The sutures and parietal foramina were totally obliterated.

The fourth and most interesting specimen is from the body of a female 72 years old. The whole cadaver except the lower portion of the face, suggested senility and considerable loss of

Fig. 18 Deep 'senile' excavations in the parietals with the accompanying brain.

weight relatively shortly before death. The deep parietal excavations shown in figure 18 attracted attention as soon as the body was unwrapped and recalled the descriptions of Humphry, Maier and Smith and an illustration in Ziegler ('02). Comparatively slight sagittal pressure on either side in these areas, produced the peculiar crackling sound of thin bone.

The scalp was not abnormally adherent anywhere but the calvarium was apparently very thin except perhaps along the

ridges which surrounded the depressions. The large frontal sinuses were outlined indistinctly through the thin lamina externa. Upon removing the calvarium the dura was found decidedly adherent to the calvarium as is customary in old skulls. It was especially adherent over part of an area 2 by 1 cm. where the inner table of the right frontal sinus was completely absent. The dura here fused with the sinal lining which was not especially adherent to the bony wall. There was no evidence on this calvarium of bone formation, except in the region opposite the left pterion where a small rough hemispherical nodule 7.5 mm. at the base and 3.5 mm. high projected into the cranial cavity. This nodule which was imbedded in the posterior end of the mid-frontal gyrus, was somewhat adherent with its base, to an oval depression to a rough plate of bone about 6 by 10 mm. in size on the inner table. The rough scale-like character of the inner table in the region of the frontal sinuses, a few scattered much smaller plaques of bone on the inner table and the deep arterial sulci with steep walls all suggested the deposition of bone on the interior.

As indicated by the depth of the fossae the absorption of the parietals is almost complete on both sides, their thinnest portions measuring less than 0.5 mm. over several small areas and less than 1 mm. over the whole of the rest of the floor of the depression which covered oval areas about 4 by 3 cm. These areas as measured on the level of the outer table were approximately 8 by 5 cm. large and were surrounded by a slanting wall about 1 cm. high. Although the thickness of these surrounding bounding walls on both sides, measured from 9 to 12 mm. the rest of the calvarium in the non-depressed areas was only 7 to 10 mm. thick. In addition to the marked absorption in the areas mentioned, that in the temporal regions was also very noticeable, yet this calvarium still measured 1.6 mm. in thickness, at a point 2.5 cm. above the internal occipital protuberance. About 3 cm. above the external auditory meatus it measured 3.8 mm. Although the thickness of the calvarium 1.7 cm. above the orbits was 1.7 cm., the inner table which was

absent in some places opposite the frontal sinuses was only 0.75 mm. thick and the outer only 1.25 mm.

Numerous small areas of total absorption were also present over comparatively large areas of the tegmen tympani. The three largest of these areas in the tegmen measured 3 by 2 mm. and while those on the right side were smaller the tegmen nevertheless looked honey-combed. Small absorption areas extend anteriorly quite close to the sulcus for the middle meningeal artery. The digital impressions and juga cerebralia were not very evident.

The brain showed no very marked atrophy but the arachnoid was very thick especially over the whole frontal region. It was web-like and not unlike loose cotton in gross structure, about 4 mm. thick and very adherent throughout. After fixation in formaline the brain weighed 1035 gm. The stature of the body was 158.3 cm.

The evidences of senility were not confined to the skull, however, for the ribs were represented by a mere shell of very thin, pliable bone which could easily be compressed between the fingers. The costal cartilages except the first, however, showed no signs of calcification even in their interior. They contained only a few small grayish dots which had not, however, proceeded to the stage of calcification. The laryngeal and nasal cartilages were not calcified either and the mandible was not markedly senile. The preservation of the latter was due to the fact that portions of the lower incisors, the canines, the left and right lower premolars, the roots of the first right lower molar and the stumps of two roots of the second right lower molar were preserved. That the roots of the absent teeth had not been lost very long before death is shown by the irregularities of the gums due to unabsorbed remnants of the alveolar processes. The rest of the skeleton is markedly senile.

I have also been repeatedly impressed by the character of a general absorption occasionally seen in the posterior region of the parietals. Not rarely this absorption stops almost completely when the lambdoid suture is reached thus causing the squama of the occipital to rise like a wall along the suture. It

is exceedingly difficult to understand what can be responsible for the character of the absorption in this region of the parietals. The lambdoid suture appeared normal in all these cases and we cannot have recourse to muscle action as preservative agents. There was no evidence of rickets in these cases.

Although the senile character of such atrophies of the calvarium as here reported has been and may be called in question, yet in these cases the atrophy probably was not due to the continuous pressure of a lesser weight, as Smith concluded for Egyptian skulls. Although the ages vary considerably the histories of these cases unfortunately are not available. The fourth case was that of a woman born in this country. Hence weight bearing with the head, can be quite confidently excluded. Moreover, the erratic location of these atrophies as well as their peculiar shape makes it exceedingly difficult to conceive how pressure could be exerted upon those areas unless the head were born well-flexed upon the chest during exertion which would interfere seriously with respiration. Besides weight-bearing or pressure of considerable magnitude and for long periods of time do not result in such atrophy.

THE RELATION OF BRAIN ATROPHY TO CRANIAL ATROPHY

A case of very marked brain atrophy in an old woman, accompanied by congenital porencephally might be expected to furnish some evidence even if slight, of the relation of cerebral atrophy to the thickness of the overlying calvarium. Since the decrease in the volume of the cerebral cortex and the accompanying enlargement of the lateral ventricles do not cause a decrease in intra-cranial pressure it might be assumed that no deposit of bone should occur on the internal surface of the calvarium in consequence of brain recession. This is especially true since in cases of hydrocephalus an increase in intracranial pressure is accompanied by thinning of the calvarium and because constant pressure from other causes has a similar effect. Nevertheless, thickening on the interior of the calvarium in the lateral frontal regions in consequence of deposit of bone from within as

noted by Humphry, ('58) is very common in connection with atrophy of the frontal lobes in senility. But until more is known about the cause of deposition of bone on the inner surface of the calvarium it would be wrong to assume that there is a causal relationship between the two. Especially since we do not know why in one case of atrophy there is marked absorption within with consequent thinning of the calvarium and decided broadening of the arterial sulci with their final obliteration through absorption, while in the other, on the contrary, there is just as marked a thickening in consequence of deposition within accompanied by deepening of the arterial sulci to such an extent that large portions of the vessels may be almost enclosed.

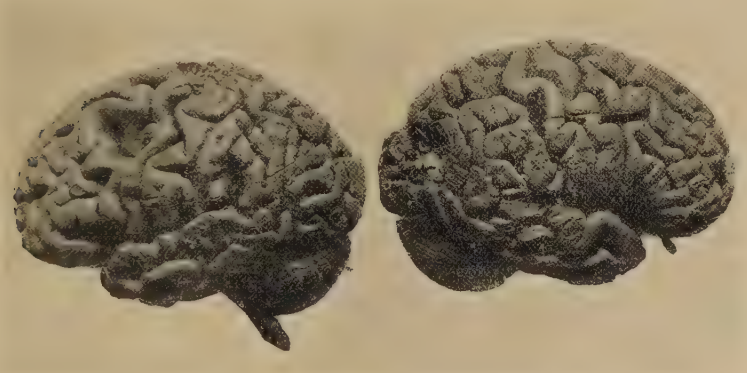

Fig. 19 Primary congenital porencephaly

The brain showed in figure 19 was taken from the body of a woman 75 years old, dead of myocarditis. Neither the skull as a whole nor the calvarium showed any markedly senile changes. After fixation in formaline the brain weighed 1034 grams. However, there had been some post mortem drying and shrinkage. The meninges were normal but all the cerebral arteries were somewhat sclerotic. Atrophy of the left hemisphere seems clearly more marked than that of the right. This is evident even along the longitudinal fissure, the frontal lobe and the lateral and central sulci. Marked asymmetry in the shape and the arrangement of the gyri also exists. This is especially notice-

able in the porencephalic area which lies in the posterior extremity of the medial frontal gyrus and affects the latter and also the pre-central gyrus in the region around the posterior extremity of the inferior frontal sulcus. The defective area measures 2.9 by 2.1 cm. and is approximately 2 cm. deep. The nature of the surrounding gyri as well as the condition of the corresponding area on the right side and that of the brain as a whole seem to indicate that this defect is not due to senile atrophy but to faulty development. This assumption was confirmed by section of the brain. There were no evidences whatever of lesions and the gray substance was as thick at the bottom of the porencephalic area as elsewhere. It was merely a case of failure of this area to develop properly and the defect is hence truly congenital.

The peculiar arrangement and form of other gyri also suggests this. The arachnoid bridged over this depressed area and the overlying calvarium showed a gently rounded eminence on the interior and also a corresponding depression on the exterior. The calvarium here was also slightly thicker than the corresponding area on the other side but because of the corresponding depression of the outer table this increase in thickness was only very slight. The respective thicknesses at corresponding points on the two sides of the calvarium were 8 and 6 mm. The fact that the outer table was depressed over this area also indicates, it seems to me, that the local cerebral deficiency was a congenital rather than an acquired defect for, with the latter, one might expect a thickening of the calvarium from within unaccompanied by a depression from without.

Although the left hemisphere plainly looked more atrophic than the right it nevertheless weighed 11 grams more. The measurements for length, breadth and width of the two hemispheres were practically equal, but considerable differences between the volume of the two ventricles was found to exist. The volume of the right ventricle was 24 cc. and that of the left 20 cc. which accounts in part for the deceptive appearances. The volume of these ventricles is also considerably above the average found by Harvey ('09) who gave the ventricular volume for

brains with an average weight of 1314 grams as 15.08 cc. for the left and 13.49 cc. for the right side. Considerable differences in ventricular volume were encountered, however, by Harvey.

The character of this calvarium does itself not suggest senility. The parietal foramina are obliterated but the lambdoid suture is still preserved within, and the coronal sagittal and lambdoid sutures, especially the last two, are still well-marked externally. The whole inner surface of the calvarium is slightly rough, however, plaques of new bone are found here and there and the region of the superior sagittal sinus is marked by a broad ridge which was apparently moulded upon the broadened longitudinal fissure. No absorption areas are present externally and the arterial sulci are not especially marked. Indeed, those over the depressed portion of the calvarium which covered the porencephalic area are especially shallow thus also suggesting that there has been no special deposit of bone there. The thickness of the calvarium in the lateral frontal region is 1.1 cm. The diploe are sclerotic and the calvarium which has a thickness of 5 mm. in only a few places, is heavy and strong.

The clinical history of this case could not be obtained but a careful examination of the entire body revealed no evidence of defective muscular development or of asymmetrical atrophy as a result of developmental conditions or of paralysis. Section of the cord showed it to be symmetrically formed and no gross signs of degeneration could be detected.

The greatly emaciated condition of the cadaver was rather puzzling and remained unexplained until the stomach was opened. It was somewhat dilated but otherwise normal save for the presence of a papilloma directly in front of the pyloric orifice. This tumor which was 3 cm. long arose from an enlarged base which lay partly upon the gastric margin of the pyloric sphincter but which was not adherent to the gastric musculature. The body was 1 cm. wide and 0.5 cm. thick being flattened dorso-ventrally and the free portion distinctly papillamatous.

The pyloric musculature was not hypertrophied and the base of the tumor was alone sufficient to completely obstruct the ori-

fice. Since the papilloma was freely movable its inclination toward the antrum probably did not prevent it from being forced against the pylorus and thus further obstructing the passage of gastric contents into the duodenum. Hence it seems highly probable that this woman suffered much from gastric trouble and that her emaciation was largely due to the mechanical difficulty caused by the tumor.

THE CAUSE OF SOME LARGE PARIETAL EMINENCES

It is usually stated that large pariteal eminences are due to a local displacement outward of both laminae of the skull. In the great majority of cases this explanation holds but in case of

Fig. 20 Outline of a cross section of calvarium with a large parietal eminence

the calvarium outlined in figure 20 the large parietal eminence on the right plainly has a different origin. As the figure shows, the inner table of this skull has suffered no outward displacement whatever and the prominent eminence is due to a considerable thickening and a gradual deflection of the outer table. Sclerosis of the diploe is present and several areas of dense connective tissue and what looked like red marrow, are interpolated between the two tables the space between which is largely filled in by compact bone.

This calvarium which was taken from the body of a man 70 years old at time of death, is heavy partly because sclerosis is so complete in the frontal region and also because the calvarium

as a whole shows only slight evidence of absorption. Although the arterial sulci are only slightly deeper than normal, very evident thickening in the interior in the lateral frontal region is nevertheless present.

The greatest thickness of the right parietal eminence is 15.5 mm. and the thickness of the corresponding point in the left is 8.5 mm. The greatest thickness in the left lateral frontal region is 1.0 cm. and 0.9 cm. on the right. The thinnest point in this calvarium is in the right temporal region where the section measures only 2.5 mm. yet in spite of the thinning in this region the whole calvarium does not even remotely suggest senility. It is true that all the sutures are well obliterated and that the sagittal suture is marked by a very slight sulcus which extends over the metopic suture which can be recognized still. These things are, however, of but little moment. The right parietal foramen is still evident and there is no indication of concentric atrophy in that region.

The periosteum was not especially adherent over this bosse which measured 6 by 4 cm. in the sagittal and parietal planes respectively. Its surface is very smooth and it looks denser; that is whiter; than the rest of the calvarium but there is no good evidence of the presence of a pathological process and the rest of the skeleton was wholly normal.

EXTENDED FUSION OF THE SECOND AND THIRD RIBS

Although more or less extensive bifurcation of ribs is relatively common fusion is much rarer. In fact Bland-Sutton ('99) stated that fusion of the ribs resulting in the formation of bicipital ribs occurs only in connection with the cervical ribs or in relation to the first and second ribs. Disse ('96) made a similar statement. Dwight ('07) however, held that a bicipital rib may occur also by the fusion of the first thoracic with the second beyond the tubercles. Merkel ('99) in a fine summary, merely states that anomalies occur at the posterior ends in the region of the tubercles where the ribs may send processes toward each other and a similar statement is made by Nicolas ('11)

and Thompson ('14). In Rauber-Kopsch ('11) it is stated that now and then it is observed that the margins of two or more ribs may fuse for a greater or lesser distance. This statement was also made by Thompson ('13) who merely said that fusion of adjacent ribs may occur. In the second edition Thomson referred to Meckel.

Campbell ('69) reported a remarkable case of union of a number of ribs by cartilage and also by bone accompanied, however, by multiple exostoses and also by the formation of bone in the diaphragm and of cartilage in the right lung. The presence of so many exostoses and the occurrence of bone formation in the soft tissues makes it probable ,however, that, in this case, the union of the ribs was due to a pathological rather than a developmental process.

Turner ('70–'71) referred to a case of fusion of the first and second ribs reported by Hunauld in 1740. Hunauld is also said to have possessed a fetal skeleton from the seventh month in which the upper five left ribs were united posteriorly and in which the sixth and seventh ribs were also partially united. In this article Turner pictured two specimens of fused ribs which from comparative anatomical considerations, he apparently declared to be fused cervical and first ribs. In a later article Turner ('82–'83) concluded that the two specimens in question were fused first and second ribs.

A fuller account than that contained in any of the above texts and handbooks is that given by Lane ('83). Lane gave several instances of fusion of a cervical with a first rib and of fusion of the first and second ribs. He found the common shaft formed by the union of the first and second ribs in one of his cases, $1\frac{1}{8}$ inches broad dorsally with a maximum width of $2\frac{1}{4}$ inches. The latter point was located $1\frac{1}{4}$ inches behind the termination of the lower rib. Unfortunately Lane did not give the length of the union but judging from his drawing this was as long as the breadth of the united ribs or $2\frac{1}{4}$ inches. Although the ribs in this specimen were said to be firmly united the "outer surface of the shafts still remained very prominent after fusion, being separated from one another by a deep groove. The inner surface of the com-

mon shaft was smooth, however, and presented no irregularity or ridge of any sort." Lane remarked that this specimen is peculiar in its great breadth and in the thinness and incurvation of its lower part.

Two similar cases were previously described by Turner, and Bryce ('15) stated that Valenti ('03) also described a case of fusion of the second and third vertebra accompanied by 'apparent' fusion of the second and third ribs for the greater part of their length.

The most comprehensive study of the occurrence of variations in ribs is that by Hrdlicka ('00) who examined over 1600 ribs

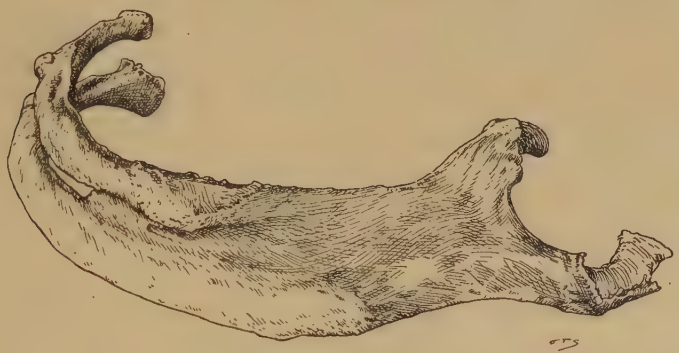

Fig. 21 Fused second and third ribs

and numerous Indian skeletons. In an examination of this large amount of material, Hrdlicka found only one case of junction of the third and fourth ribs but three cases of the much more common anomaly—fusion of the first and second ribs.

The specimen shown in figure 21 was taken from the cadaver of an old man, is composed of the second and third ribs. The rest of the skeleton was normal and the thorax was not unusually asymmetrical. Hence the anomaly was not very evident and my attention was called to it by Messrs. Supple and Tufts, two of our students. These two ribs which are of normal length were fused throughout three-fourths of their length. Nevertheless their relations were maintained exactly for they had independent cartilages and a short bifurcated medial extremity.

Unlike the specimens of fused first and second ribs described by Lane, the individual shafts are almost completely obliterated in the medial half of the fused portion, both within and without. This is true of a rhomboidal area lying within 8 cm. of the sternal extremity of the second and 7 cm. of the same extremity of the third rib. The intercostal groove is only very slightly preserved on the external surface of the lateral half of the fused portion. Since the fused portion extends to within 9 mm. of the medial extremities the appearance here is that of a bifurcated rib. The common shaft is 12.3 cm. long, the first rib 22.8 cm. and the second 26.5 cm. The width of the fused portion is 3.5 cm. laterally, and 4.3 cm. medially but the distance from the superior border of the first rib to the inferior border of the second rib at the medial extremities is 6.1 cm. This increase in width is due to the fact that the short non-fused medial extremities diverged rather markedly to meet the costal cartilages. The distance from the mid-point of the head of one rib to the midpoint of the head of the other is 2.1 cm. or normal.

In the lateral area of fusion the second rib is very definitely outlined for a distance of 4.3 cm. and the third for a distance 7.9 cm. Throughout this region of only partial obliteration of the shafts the intercostal region is marked by a broad deep sulcus and the outlines of the individual shafts are well preserved externally but not internally, where the intercostal region is marked by a decided ridge which gradually disappears toward the medial extremity. This rounded ridge looks not unlike the inner surface of a rib and gradually merges with the shaft of the first rib. The subcostal sulcus of the second rib is fairly well marked to a point of 2.5 cm. beyond where the fusion begins but that on the first rib extends 4.5 cm. beyond this point. The greater length of the sulcus on the first rib is due to the fact that it lies external to the bony union between the ribs for a distance of 4.3 cm. The intercostal nerves ran internal to the fused portion.

The superior margin of the flat, fused area is much thicker than the inferior, the two measuring 6 and 2.5 mm. respectively. The greater thickness of the superior margin is due to the better development of the bony area which would be comprised by the

second rib. In thickness, spacing and form where separate, and also in length where fused the ribs are entirely normal. The intercostal muscles are of course absent in most of the fused area which is covered by a strong intercostal membrane. The muscles are present, however, in the lateral portion of the fused area where the external portion of the bodies of the individual ribs are only partly unaffected by the fusion.[2]

BILATERAL ABSENCE OF THE EXTENSORES CARPIULNARES

Such a variation as the above is not mentioned by Le Double ('97) or in the larger handbooks such as those of Bardeleben and Poirier et Charpey. Neither do Quain nor any of the other German and English textbooks consulted speak of it. Gruber ('85) and Turner ('85), however, each reported a somewhat similar case. Gruber also says that he could not find anything like it in the literature.

Gruber observed the specimen reported by him in 1883, in the left arm of a young male 20 years old. It was the only specimen observed by Gruber in the course of the personal dissections of 600 arms! In this case the muscle was represented merely by a tendinous strand which extended, however, all the way from the external condyle to the fifth metacarsal. This strand which was fused with the fascia was 5 mm. wide above, 3 mm. wide and 1 mm. thick in the middle of the forearm and 4 mm. wide and 2 mm. thick at the point of insertion. The lower portion was supplied with a vaginal sheath and lay in an ulnar sulcus of normal dimensions. Other fairly common muscular variations were also present in this arm.

Turner who referred to Gruber said the case observed by him was wholly comparable to that of the former. In Turner's case also, the sulcus on the ulna was normal although the ten-

[2] Through the courtesy of Dr. Hrdlicka, it has since been my privilege to examine specimens of fused ribs in the Smithsonian Collection, and if I remember correctly, one of the specimens is very similar to what is here described. Through the courtesy of Dr. Lamb I was also enabled to examine a specimen of extended fused ribs in the museum of the surgeon-general, which belongs still lower down in the series of ribs.

dinous slip was only one-sixth the size of the normal tendon. Turner emphasized that such an anomaly was not mentioned by Macalister or Testut in their works on muscular anomalies, and that this case was the only one observed by him in thirty years' experience in the dissecting room.

A very careful examination of both upper extremities of this male subject by Messrs. Supple and Tufts who noted the absence early in their dissection, and by Professor Congdon and myself did not reveal a trace of these muscles. It seemed to me at first that a remnant of the tendon had fused with the internal lateral ligament of the wrist but a comparison showed that this ligament varies sufficiently in strength and distinctness to justify one in including those on these arms among the normal variations.

Although the extensores carpi ulnares muscles were completely absent in these arms the sulci on the dorsal surface of the distal extremities of the ulnae, in which they lie were nevertheless present and practically normal in size and depth. Hence these specimens again illustrate a certain independence in the formation of these and similar sulci, which nevertheless may be moulded by tendon pressure even if not primarily due to them No other anaomalies were found in this cadaver and no unusual strands or thickenings were present in the fasciae of these forearms. No modifications could be determined in the fifth metacarpals.

UNILATERAL ABSENCE OF THE TWELTFH RIB IN AN ORANG-OU-TANG

In a skeleton of an adult orang-ou-tang which seems to possess no other unusual characters the condition of the ribs deserves a word of comment. There are eleven pairs of ribs which look normal except for the development of a flat wedge-shaped square bony process one centimeter square on the anterior upper surface of the tenth rib. This process which is 3 mm. thick at the base arises from the superior costal border a few centimeters ventrally from the angle and must have come close to the inner surface of the superior rib although the latter bears no sign of such contact. Many of the ribs on both sides also bear triangular bony extensions along their inferior borders in the re-

gion of the angles a condition which may, however, for all I could learn, not be uncommon in the orang-ou-tang. The right transverse process of the nineteenth, or first lumbar, vertebra looked, practically like the corresponding process in human skeletons. The accessory and transverse processes were very well differentiated and were marked by a deep sulcus. The mammillary process though slender was well-developed and was separated by a broad deep sulcus from the inferior processes.

The left transverse process, on the other hand, had the typical form except that its extremity was pitted by a very definite articular cavity which received the head of the twelfth rib. The latter was 8.8 cm. long and the eleventh ribs 18.2 cm. It is particularly interesting that although the twelfth left rib did not articulate with the body of the vertebra but arose from the transverse process the right transverse process nevertheless showed no enlargement whatever and possessed a better differentiated accessory mammillary and transverse processes than most human vertebrae.

THE EFFECT ON THORACIC FORM OF COMPLETE DESTRUCTION OF ONE LUNG

Although the expression "One lung is gone" is not unfamiliar to medical students and to physicians who deal with large numbers of tubercular subjects it is necessary to recall that those words as customarily used by clinicians are not intended to be taken literally. Moreover, when one considers the great vessels in the root of the lung such a thing seems quite impossible. It would seem that death from hemorrhage must occur long before the great pulmonary vessels so near to the heart can be obliterated. Yet such a case recently came to my attention.

The cadaver was that of a man beyond middle age and nothing which could be identified with the naked eye as pulmonary tissue remained of the left lung. The remnant of the pleurae was roughened and thickened considerably and the remnant of the root of the lung, was represented merely by a short stub of dense connective tissue containing the sclerotic and wholly, or partially obliterated extremities of the bronchi, blood vessels and calcified lymph nodes. The left thoracic cavity contained

but very little coagulum and was otherwise completely empty. The left dome of the diaphragm was but slightly displaced. The fact that the mediastini and the contained viscera were displaced so slightly is likely explained by the thickening of the left parietal pleura long before the lung was completely destroyed.

I have not sufficient knowledge of either tuberculosis or pathology to venture a statement on the probable sequence of events in this case but the fact that the external form of the thorax was altered so slightly that it attracted no attention, does seem to indicate that not much tension could ever have been exerted on the thoracic wall as a result of an adhesive pleurisy. I recall that Hutchinson found that the long-expressed idea that tubercular individuals are flat-chested is erroneous but these findings do not imply that tuberculosis never affects thoracic form. Hutchinson found that the anterior posterior diameter in normal adult males between the ages of twenty to forty-four is 71 if the transverse diameter at the level of the nipple is taken as 100. This same diameter in 82 clinically tubercular subjects was found to be 79.5 and in 30 flat-chested individuals 80.

Instances in which the thoracic form has been profoundly changed especially in cadavers in which the ribs are markedly senile, are, of course, frequently seen in dissecting rooms where most of the material used is from the senile or tubercular or from the senile and the tubercular. But it is difficult to see how a lung can be completely destroyed by tuberculosis without an attendant pleurisy and consequent long-continued tension on the chest wall as a result of fibrosis. Nevertheless, the conditions were as here represented and there can be no doubt about the tubercular nature of the disease in this particular case.

OSSIFICATION IN THE ARACHNOID

The occurrence of small hardened areas in the spinal arachnoid is comparatively common in dissecting room cadavers. Because of this fact and also because these areas are usually very small I have in the past usually taken them for calcifications.

This assumption was based not only on their appearance but also on their physical properties. Some months since my attention was called to certain small areas of apparent fibrosis of the arachnoid and to other very much larger horny plaques. Mr. H. M. Winans and Miss Dorothy Wood, two of our medical students noticed these peculiar plaques in the lower dorsal region upon exposing the spinal cord. The largest of them has an area of 2.8 by 1.6 cm. and the next largest 2 by 1.4 cm. Both were less than 0.5 mm. thick, however, and were moulded so as to surround the dorsal portion of the cord in the region over which they lay. They were adherent neither to the pia nor dura. Both these large plaques and the smaller similar ones were very flexible and quite translucent.

In cutting off a portion for microscopic examination it was evident that these plaques both had the hardness of bone rather than of horn and that they lacked the friableness or at least the brittleness of calcified areas. Examination of paraffine sections showed that these areas were composed of lamellae laid parallel to the flat surfaces of the plaques. The lamella contained some rather atypical bone corpuscles and were penetrated at intervals by perforating or atypical Haversian canals which here and there opened upon the surface. Several small narrow cavities were also found and the internal surface also showed a narrow calcified layer. The outer portion, on the contrary, was formed by a single layer of investing cells. The body was that of an Irish woman of 75 who had died of arterio-sclerosis and in whom the porencephalic brain referred to on page 76 was found.

In view of the close relationship between fibrous tissue and osteogenetic processes, the mere presence of bone in the arachnoid is nothing particularly surprising. A discussion of this subject in man and animals with references to the literature and numerous interesting personal observations is given by Cushing and Weed ('15).

CUTANEOUS PIGMENT IN THE SPERMATIC FASCIA

Although small quantities of cutaneous pigment are found in the cutis of man I am not aware that the so-called superficial fascia has been found pigmented. It is true that Toldt ('13) found that the epidermis in the dark skin spots in Macacus inuus and Cebus libidinosus contained very little pigment and the deep layers of the corium much, but this pigment was intra and not intercellular for it was contained in large branched pigment cells. Toldt also emphasizes the relatively great pigmentation

Fig. 22 Spermatic fascia from Didelphys virginiana

in the corium of these mammals as compared to the lower vertebrates. Adachi ('03) on the other hand concluded that there is a correlation between the intensity of epidermal and dermal pigmentation but found that the quantities of pigment contained in the cutis were relatively small. Breul ('96) and Frederic ('06) strangely enough found pigmented places in the corium most common in the relatively unpigmented regions.

In figure 22 a portion of the spermatic fascia of an opossum is shown. The surface marked *S* is the superficial one and that marked *D* the deep one. As shown in this figure large masses of pigment are scattered about in almost the whole of this fascia

the superficial layers of which contain thick layers of pigment. In addition to these larger masses pigment granules were also scattered about in the fascia but practically all of the pigment was extra-cellular. Although I am not here concerned with the finer questions relating to the origin and occurrence of normal skin pigment there can be little doubt that we are dealing with normal cutaneous pigment. The gross character of the overlying skin alone makes this certain.

The scrotum and the para-scrotal skin of this opossum was intensely bluish black. The color of this area made it look like 'tache bleuatre,' the peculiar shade being of course due to corium pigment. Since smilar pigmented areas as found in the scrotal region of this opossum are relatively common in mammals and since other similar areas were found on this very animal the scrotal pigmentation attracted no special attention until the skin and some of the superficial fascia had been reflected, butcher-wise, and the testes were seen to be just as intensely bluish black. On incising the spermatic fascia and reflecting the parietal tunica vaginals with it, the testes were seen to have the usual color.

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THE HYPOPHYSIS OF THE GUINEA PIG

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SEVEN FIGURES

The guinea pig was used as the object of this study because it is readily obtainable and also because though thousands are used yearly for experimental purposes, this animal has been neglected from an anatomical standpoint. The only reference found to the anatomy of the hypophysis of the guinea pig, was one by Oppel ('14) who referred in a few lines to its general relations and another by Paulesco ('08) who quotes Fischera in regard to the weight of the gland.

The general relations of the hypophysis of the guinea pig are very similar to those existing in other vertebrates and its microscopic structure is quite similar. The most striking difference found was the presence of cilia in the cleft and also in the epithelial cysts or vesicles of the glandular portion. According to Trautman ('09), ciliated epithelium has been reported in the vesicles in the hypophysis of man and the rabbit, but Trautman was unable to find any in the cysts of any of the domestic animals studied by him. These included the horse, ass, cow, calf, sheep, goat, hog, dog and cat, and although he could not be certain Trautman thought he saw ciliated epithelium in the lining of some portions of the cleft of the pituitary of the hog. In the guinea pig this ciliated epithelial lining of both the cleft and the vesicles was found uniformly present somewhere in all the specimens examined, but it was not present in all cysts nor did it completely line the clefts. Within the latter, in fact, it did not appear at all on the side adjacent to the pars intermedia and only on portions of the opposite side. These portions are easily recognizable even under low magni-

fication by the large, clear, columnar cells, which often project into the lumen, as little mounds. In some cases, however, the ciliated portion of the lining epithelium extends over considerable stretches. The fact that ciliated epithelium is present in both the cleft and in the closed vesicles of the epithelial portion seems to indicate that their origin is the same and that both undoubtedly are remnants of the lumen of the epithelial pouch (Rathke's pouch) developed from the buccal epithelium. In several cases, for example, it was possible to trace the lumen of typical vesicals to the lumen of the cleft.

METHODS

In every case a portion of the brain was removed with the hypophysis in order to retain its relations, particularly with the third ventricle. All microscopic preparations were cut serially in paraffine. Sections cut sagitally in the cranio-caudal plane were used mostly since they best show the relations of the different parts. Zenker's fixative, followed by methylene blue and aqueous eosin were found to be the best general fixative and stain. Flemming's and Orth's fluids were also used. The phosphotungstic acid-hematoxylin stain was found valuable in staining neuroglia and ependymal fibers and cells, and also reticular connective tissue. Next to the methylene blue and eosin, aqueous eosin and iron-hematoxylin were found to be most satisfactory. The latter stains the cell boundaries especially well (figs. 3 and 4).

OBSERVATIONS

The hypophysis of the guinea pig is comparatively large. Measurements made upon three freshly killed adult animals show that it weighs between 22 and 32 mgm., varying somewhat in different specimens. Paulesco ('08) quotes Fischera as giving the weight of the gland as 0.015 gram, but he does not state whether his data were derived from specimens of fresh or preserved glands. By weighing the brain also in each case,

it was calculated that the gland represents between 0.52 per cent and 0.70 per cent of the total brain weight.

The measurements made on formaline fixed glands as to size gave the following averages:

	mm.
Transversely (widest part)	5
Cranio-caudally (widest part)	4.2
Dorso-ventrally (widest part)	$1\frac{2}{3}$

The brain proper, including the cerebellum had the following average dimensions:

	cm.
Transverse (widest part)	2.1
Cranio-caudally (widest part)	3.1
Dorso-ventrally (widest part)	1.1

From the above measurements it will be seen that the hypophysis is comparatively large; that its transverse diameter is about one and a fourth the cranio-caudal diameter and that it is much flattened dorso-ventrally.

The general relations of the gland to the brain are indicated in figure 1, which is a semi-diagrammatic sketch of the inferior surface of the brain with the dura mater removed. The hypophysis lies just posterior to the optic chiasma in an almost horizontal plane, being practically parallel to the plane of the base of the brain. The cerebrum, descending on either side, forms a considerable fossa in which lies the pituitary with its dural sheath, the blood vessels and sinuses. Laterally on either side and partly covering it, lie the two very large fifth nerves with their ganglia. The gland is attached to the tuber cinereum by a comparatively long stalk which expands posteriorly forming the pars nervosa. In the figure only a small portion of the pars nervosa is visible posteriorly, from the inferior surface, for the greater part of it is covered by the pars glandularis. The dorsal end of the gland is free except where it is attached to the brain by the blood vessels which enter its superior surface.

The dura mater forms a distinct pouch or pocket for the whole gland and is much thickened behind where it is often cartilaginous in old animals. In section it shows that it is split off from the main dural covering of the brain, but the cavity of the

pocket is nevertheless continuous with the main subdural space. The gland is loosely attached to the dura by little strands of arachnoid tissue but the space between is easily penetrated by fluids.

A large vascular sinus surrounds the posterior end of the gland in a horizontal direction between the two layers of the dura mater which is here split to form the dural pocket. Its walls are thin and composed only of a thin layer of fibrous

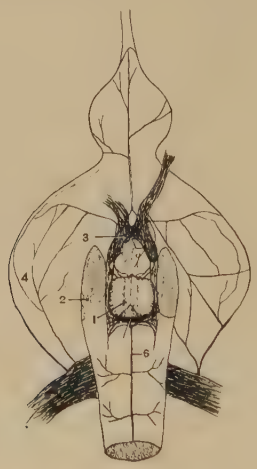


Fig. 1 Diagrammatic sketch of the inferior surface of the brain of the guinea pig showing position of the pituitary gland and its relation to the surrounding structures. *1*, pituitary; *2*, divided fifth nerve and semilunar ganglion; *3*, optic chiasma; *4*, cerebrum; *5*, small portion of pars nervosa projecting from above the pars anterior; *6*, basilar artery.

tissue lined by endothelium. The lumen fits the space between the two dural layers and therefore has a general triangular shape but it is often irregular. Sometimes it partially replaces the subdural space extending anteriorly over the superior or inferior surfaces or over both for varying distances. In these cases the fibrous layer is inseparably fused with the capsular layer of the gland. In animals in which the arterial system was injected with India ink this sinus shows very distinctly as a black line extending around the posterior end of the gland.

About the middle of the posterior end of the gland there is a smaller connecting sinus which extends directly posteriorly within the dura mater, presumably forming a connection with some other blood vessel. There is nothing to indicate the function of these venous vessels but it seems probable that they drain some portion of the pituitary, probably the meninges. The circular sinus of the pituitary was found in every series of sections observed but the sinus passing posteriorly could only be seen when the knife happened to pass parallel to its lumen. That they were sinuses and not lymph channels, was shown by the fact that they were often engorged with blood.

The hypophysis with its dural covering, lies upon the posterior third of the body of the sphenoid bone. The sella-turcica is represented only by a small fossa, at the bottom of which there is usually a small opening. If closure of the cranio-pharyngeal canal is partly or wholly prevented by the persistence of the epithelial stalk, this minute aperture, opening into the bone may thus remain. In no case, however, had the stalk retained its epithelial structure and in most cases no trace of it could be found. Within the sphenoid the canal is more or less obliterated by encroachment of the bone. On the pharyngeal or inferior surface a second foramen which transmitted the buccal end of the stalk is sometimes seen.

The relations of the different parts of the hypophysis can best be understood by referring to figure 2. The epithelial portion lies upon the inferior surface and is represented by the darkened area. In section it appears smaller than the light area or pars nervosa but, owing to the fact that it extends so far laterally, amost surrounding the nervous portion here and anteriorly actually doing so (*9*) it is really considerably—probably a third—larger than the pars nervosa. It extends as a thin epithelial layer anteriorly over the neck and also over the base of the tuber cinereum. For this reason this part is called the pars tuberalis (*4*) by Tilney '14. Tilney claims for it a separate development from Rathke's pouch.

The infundibulum cerebri (fig. 2) is a continuation of the brain backwards and slightly downwards. It originally con-

sisted of brain tissue but apparently degenerates laterally into a connective tissue mass containing a few epithelial cells. Colloid is found in the meshes but this probably has its source in the pars intermedia. The infundibulum which is funnel-shaped near the base of the brain becomes comparatively small at its neck and at the distal end widens out into a club-shaped mass, which forms the main portion of the pars nervosa. In some animals, notably the cat, the posterior lobe is hollow, but in the guinea pig it is nearly solid, the opening from the third ventricle ending in the neck as seen at *5* and *6* in the figure. The

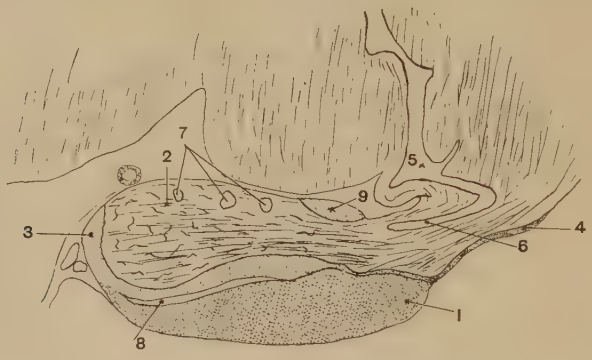


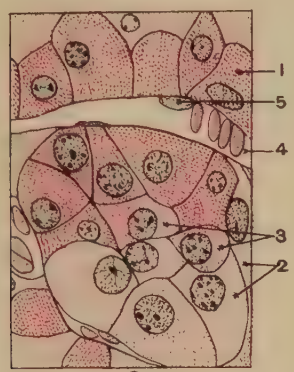
Fig. 2 Median sagittal section through pituitary of adult guinea pig. (Semi-diagrammatic.) *1*, pars anterior; *2*, pars nervosa; *3*, pars intermedia; *4*, tongue-like process of pars tuberalis of intermediate lobe; *5*, third ventricle; *6*, recessus infundibuli; *8*, cleft; *9*, portion of intermediate lobe which completely surrounds the pars nervosa.

end of the cavity usually enlarges to form a small irregular bulb. In most cases the nervous lobe is not absolutely solid but contains cysts (*7*) of varying size which are presumably remnants of the foetal condition in which the lumen of the third ventricle extended down into the body of this lobe.

The pars glandularis is differentiated into two portions, the pars anterior (*1*) and the pars intermedia (*3*). These parts are partially separated by a cleft (*8*) which is described as the remains of the lumen of Rathke's pouch by Tilney '14, Herring '08 and also by others.

THE PARS ANTERIOR

The pars anterior is composed of columns of epithelial cells with blood sinuses separating them (fig. 3). Presumably, the secretion from the cells is absorbed directly into the circulating blood. The cells of the pars glandularis are large and glandular and have different staining characteristics. Usually there is a distinct investment of basophilic cells upon the peripheral surface, the interior being composed mostly of acidophile



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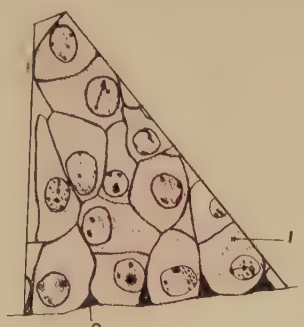

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Fig. 3 Drawing made from section of pars anterior of guinea pig's pituitary. Stained deeply with iron hematoxylin and aqueous eosin. *1*, deeply staining acidophile cells with large granules; *2*, nearly clear cells slight,l stained (neutrophiles); *3*, intermediate stages; *4*, blood sinus containing blood corpuscles; *5*, large nucleus of cell lining blood sinus.

Fig. 4 Section of pars intermedia of pituitary of adult guinea pig stained with iron hematoxylin and aqueous eosin. *1*, typical cell with fine granules; *2*, branched supporting cells. The base of the drawing is the part adjacent to the cleft.

cells. The nuclei are large and distinct and show many variations in regard to the chromatin. A peculiarity of this portion of the gland is the marked richness of the blood supply. In this respect it differs remarkably from the pars intermedia in which the blood supply is very scanty indeed.

There has been much discussion of the significance of the different staining characteristics of the cells of the anterior lobe but it is not necessary to give a historical account of the

different opinions here. Herring '08 considers the subject in some detail. It suffices to say that some authors describe three and four different kinds of cells according to differences in staining and ascribe different functions to each. Others claim that the different staining characteristics are due to differences in secretory activity of the cells. My observations upon the guinea pig tend to confirm the latter view. The different staining characteristics are, of course, always present to a very striking degree. With methylene blue and eosin, some cells are notably acidophilic, others notably basophilic. But between these two extremes all gradations in staining were found (fig. 3). Nor could any uniform difference in the shape and size of the differently staining cells be seen. The structure of the nuclei is apparently the same and they are subject to the same irregularities in size in the different types of cells.

In addition to the cells which constitute the anterior lobe proper which were described above, there are reticular cells which can be recognized by their opaque and uniform stain and also the cells lining the bloodvessels.

The pars anterior is nowhere in contact with the pars nervosa for a portion of the pars intermedia always intervenes. No colloid is found between the cells of the pars anterior but the vesicles especially characteristic of the pars intermedia were also occasionally found.

The portion of the anterior lobe which lines the cleft is composed of a single layer of epithelial cells. These cells are sometimes irregular, cuboidal or columnar. The columnar cells are usually ciliated. They are most regularly found at the posterior end of the cleft but may appear in little mounds anywhere along the cleft on the side adjacent to the anterior lobe (fig. 6). Beneath this layer of epithelium there are usually found true capillaries and spaces which may or may not be lymph spaces as suggested by Herring. In this portion connective tissue cells are most abundant.

THE PARS INTERMEDIA

The pars intermedia or juxta-neural portion is described as arising from the same source as the pars anterior, namely from Rathke's pouch. In a guinea pig at birth there is little differentiation between these portions but in the adult the difference is striking. There are no intensely acidophilic cells in the pars intermedia (fig. 4). At the point of junction at either end of the cleft, the change from the intensely red cells in cases of eosin staining, usually found in that region to the smaller lightly staining cells of the pars intermedia is quite abrupt. Herring ('08) found that this is not always the case in the cat, but in the guinea pig the abruptness of the transition was quite striking in every series of sections examined.

The pars intermedia partly invests the pars nervosa. The whole of the inferior and lateral surfaces and the greater part of the superior surface of the latter is covered by a comparatively thick layer of epithelial cells. However, posteriorly and superiorly there always is a region in which there is no epithelial investment. Here many of the bloodvessels of the pars nervosa enter, and just within the nervous substance, lie the remnants of the lumen developmentally continuous with the third ventricle, which are shown in figure 2. It may be significant that these remnants, or residua of the lumen, are always found in that region. They often get so near the surface that only the general connective tissue covering of the gland lies between them and the subdural space. In no case, however, could an opening from one into the other be found.

The cells of the intermediate are slightly smaller than those of the anterior lobe. Their nuclei are perhaps a little smaller but they have the same general appearance and stain uniformly. They are slightly acidophile but with an excess of basic stain will stain basic. Sometimes they are finely granular but they never contain the coarse granules of the acidophilic cells of the anterior lobe. Connective tissue cells are quite abundant especially along the cleft, where the branched supporting cells are much in evidence (fig. 4). According to Retzius who

is quoted by Herring, these cells in the cat "are for the most part small and thread-like and reach through the whole border. Others do not pass through but are branched. The cell nuclei are often placed near the outer end, while the inner end widens to a three-cornered foot, which is placed against the nervous tissue of the posterior lobe." With the stains used, it was impossible to confirm these statements satisfactorily in the guinea pig, but supporting cells extending from the cleft towards the pars nervosa were seen. They were branched and unbranched. and their enlarged nuclei usually were situated between the extreme ends of the cells lining the cleft or just within their outer border. In the former case they appear as little black triangles (fig. 4) which were moulded to fit the inter-space between the cells while, in the latter, they were much elongated and usually more transparent.

A very striking difference between the pars anterior and pars intermedia is the great wealth of blood supply in the one and its almost total absence in the other. A few capillaries only were found in the posterior portion of the pars intermedia but in the anterior portion, especially where it caps the pars anterior in the region of the neck, a great many were found which pass into the large arteries and veins of the neck of the infundibulum. In this case, however, the capillaries are comparatively large and apparently furnish only a small supply of blood to the surrounding tissues. However, at the junction of the pars intermedia and the pars nervosa there is usually an abundant vascular supply. In sections a vessel containing erythrocytes can nearly always be identified between these two portions of the hypophysis.

THE CLEFT

The cleft which partially separates the pars anterior from the pars intermedia, is a persistent portion of the lumen of Rathke's pouch. Upon the further separation of the infundibulum from the pharynx by the growth of the intervening parts, the infolding pouch is described as being drawn out into a long tube connecting the bulbous expansion of the cranial end with

the pharynx. The tube ultimately disappears, but the bulbous expansion partially remains and is represented in the adult by the cleft of the pituitary. It is always present in the guinea pig but it is not nearly so extensive comparatively as in the cat. Posteriorly and laterally it is often branched and irregular. In these localities cysts are most often found, especially at the posterior and anterior ends of the cleft. These evidently are portions cut off from the main cleft, which retain the original lumen as the lining of the cysts. The cleft is lined superiorly and posteriorly by the epithelium of the intermediate lobe; inferiorly and anteriorly by the cells of the anterior lobe. These lining cells are sometimes high columnar and ciliated and are usually only one cell deep.

The 'colloid' vesicles or epithelial cysts or acini,—various names are used synonymously by different authors—are especially characteristic of the pars intermedia. These cysts are of varying size, being usually largest and most numerous at either end of the cleft and, as pointed out above, are without doubt, merely portions of the original epithelial pouch, which have been cut off from the original lumen in the process of its partial obliteration. The cysts are surrounded by a single layer of epithelium. In some cases this is cuboidal but in others it is high columnar and ciliated. Some cysts contain both kinds of cells. One end of a cyst may have low cuboidal cells which further on, may gradually assume the typical high columnar form. The fact that portions of the epithelial lining of these cysts are usually ciliated and that the same type of ciliated cell is also found lining the cleft, alone strongly suggests a common origin. But what is more convincing is that in a few cases it was found possible to trace the lumen of the cyst to the cleft. Figure 5 is a drawing, outlined by the aid of a camera lucida of such a typical epithelial vesicle, the cavity of which could be traced to a direct connection with the cleft. The cell boundaries were not well-defined owing to the fact that the section was stained with methylene blue and eosin, which, though giving a high transparency and clearness does not stain the cell boundaries well. The cilia were quite clear and dis-

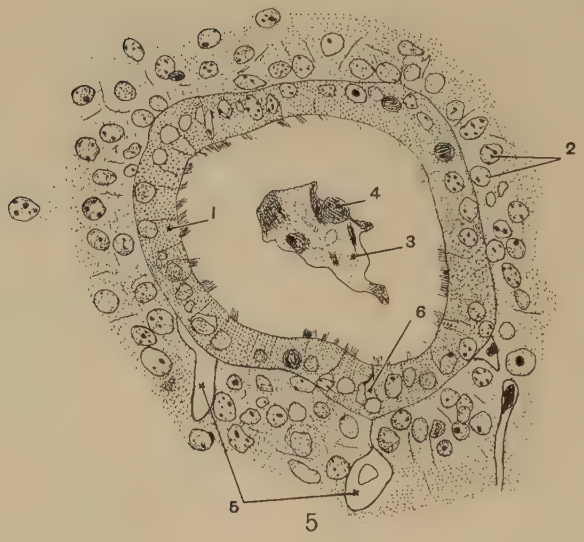

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Fig. 5 Drawing of a cyst from the pars intermedia. *1*, ciliated columnar cells surrounded by nuclei (*2*) representing cells of pars intermedia. The cell boundaries did not stain; *3*, granular contents containing (*4*) a degenerating cell; *5*, blood vessels of pars intermedia; *6*, blood vessels entering between cells of vesicle.

Fig. 6 Portion of cleft lined by ciliated epithelium. Stained with methylene blue and eosin. *1*, ciliated columnar epithelium; *2*, cells of pars anterior; *3*, blood vessel usually present above the row of lining epithelium; *4*, supporting cells. Note absence of cilia at this point; *5*, location of pars intermedia; *6*, granular fibrinous mass suggesting coagulum containing (*7*) a very large degenerating epithelial cell, the nucleus of which still contains characteristic granules.

tinct and normal looking in this specimen. In some cysts they are formed into little tufts, one for each cell, while in others they seemed to project quite uniformly from the whole circumference of the lining epithelium. In other cases they were pulled away by the contraction of the contents of the cysts during fixation.

These vesicles were rarely found in the pars nervosa also, but in no case was there ciliated epithelium lining them. In two specimens typical ciliated cysts were found lying practically wholly outside the gland in the region of the original attachment of the epithelial pouch at the extreme anterior end of the glandular portion in both cases. They were probably persistent portions of the stalk. In one of the two cases the cyst could be traced as far as the dura where it merged with the connective tissue, the bounding cells showing marked signs of disintegration.

Many authors have described colloid as existing in these cysts and also in the cleft, but none could be found in either place in the guinea pig. Its absence did not seem to be due to defective fixation or staining, for the colloid found elsewhere in the pars intermedia and particularly in the neck of the infundibulum was both well-fixed and well-stained. Most of the vesicles contained a granular mass without any particular structure evidently derived from degenerated epithelial cells, for cell detritus was often found in the mass and cells apparently being detached from the walls of the cyst were also seen. This cell detachment did not seem to be an artefact for it was found many times in areas where the other cells showed no signs of damage and were fixed perfectly. The degenerating cells, in some cases, were drawn out into a pear shape, the small end of the pear alone being still attached.

The degenerating cells in the cleft seemed to come from the pars glandularis. Some of these cells still retained their acidophile properties but did not show clear-cut granules. They contained a substance resembling mucous in appearance and staining qualities, and wholly unlike the colloid found in the posterior lobe.

THE PARS NERVOSA

There has been very much discussion of the structure and function of the pars nervosa. Some writers, notably Berkley ('94) have described nerve cells. Berkley described several different kinds of cells but the work of later investigators seems to disprove the presence of any nerve cells whatever and it seems that the earlier authors probably mistook the ependymal and connective tissue cells. The posterior lobe seems to be made up of a mass of interlacing ependymal and neuroglia cells and fibers running in a general longitudinal direction. Occa-

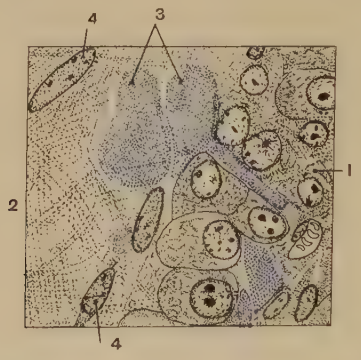

Fig. 7 Section through part of pars intermedia and pars nervosa at their point of junction. *1*, cells of pars intermedia; *2*, pars nervosa; *3*, colloid appearing both in pars nervosa and pars intermedia. Note the granular appearance of the colloid; *4*, neurolgia nuclei.

sionally there are little clumps of what may be epithelial cells, though, in the guinea pig, they are small and not characteristic. For information on the pars nervosa reference is made to Herring. Herring worked upon the cat which is an animal more satisfactory for this study than the guinea pig because the pars nervosa of the cat is hollow and its lumen directly continuous with the third ventricle.

In the guinea pig there are few inclusions of epithelial cells in the pars nervosa. Figure 7 shows a portion where the epithelial cells had pushed their way slightly into the substance of the nervous portion. It was the only place in the section.

Here, as indicated, the colloid material of the pars nervosa and that of the pars intermedia are directly continuous. In fact, one mass of colloid lies partly in both portions. It has the appearance of having been fixed while passing from the one into the other. There were few cells in the pars nervosa that could possibly be secretory. Hence it seems reasonable to suppose that the colloid secretion was passing from the pars intermedia into the pars nervosa. Physiological experiments also support this view. Moreover where the tongue-like process of the pars intermedia extends over the base of the tuber-cinereum which is not connected with the pars nervosa of the pituitary, the colloid is often found in the substance of the latter structure. In this region there are no closed vesicles as in the pars nervosa and little evidence of any epithelial inclusions. This would also seem to exclude the theory that in the guinea pig the colloid results from the degeneration of epithelial cells in the pars nervosa, and also the possibility of the secretion being produced in the pars nervosa. Colloid is often found in greatest abundance in the neck of the infundibulum. The structure of the nervous portion does not seem to account for its importance and since the epithelial cells of the middle lobe have been in contact with it from an early stage of development it would seem that its importance lies in this relationship. That is, that the secretion from the intermediate lobe passes through the pars nervosa into the brain substance perhaps on its way to absorption by the cerebrospinal fluid.

In the guinea pig the ependymal cells of the different parts of the nervous portion seem to vary. In the neck and therefore near the end of the recessus infundibuli they are quite distinct and can be traced for some distance gradually merging into ependymal fibers. In the body of the lobe, they seem to lose much in staining properties and therefore in distinctness. There are, indeed, many fibers running in bundles in all directions but they are smaller and are indistinct while the cells themselves can hardly be recognized although their large nuclei are always very striking.

The cysts found in the pars nervosa of the guinea pig presumably are the remains of the original cavity of the recesses infundibuli. They are lined with a thin layer of connective tissue, which gives no clue to its origin. In different animals, there is a variation in their size. In one specimen the opening was quite large and could be traced very nearly to the end to the retained recess in the neck. These cysts are usually filled with a granular mass somewhat similar to that found in the colloidal cysts of the pars intermedia. A lining membrane is not always present.

In every series of those sections in which the dural pocket was retained with the gland the so-called parahypophyses were found. Their most usual situation was in that portion of the dura which covers the inferior surface of the neck or infundibulum of the gland, but they were found anywhere in the dural covering of that structure. They are glandular in structure but are much degenerated and probably nonfunctioning.

In one series of sections a vesicle of the pars intermedia situated near the neck of the gland, was traced across the subdural space into the dura and in later sections appeared as a characteristic parahypophysis. Since these vesicles are probably unobliterated portions of the lumen of Rathke's pouch, it follows that these pseudoglands are merely remnants of the walls of the pouch for the two are continuous.

In two of the above series of sections, a peculiar cartilaginous structure was found, situated between the dura mater and the sphenoid bone. It had practically the same appearance in both cases in which it was found. It consisted of a comparatively long partly tubular cartilaginous structure, extending from the anterior portion of the gland to beyond the posterior end by about one third the length of the gland. That side of the cartilaginous tube adjacent to the sphenoid bone was partly missing and the remaining portion showed defects in staining and possessed no perichondrium. There was no evidence of any tearing for the edges were smoothly rounded off where the defect in the tube commenced. The cartilage next the dura was about as thick as that structure and was apparently normal. The

perichondrium was in places fused with the dura. The lumen of the cartilaginous 'tube' was lined by columnar ciliated epithelium. In some places this lining was much degenerated, but at others and particularly at either end, the epithelium was quite characteristic of the epithelial lining of the mucous membrane. Moreover, there were numerous mucous glands whose lumen could be traced directly into that of the tube, leaving no doubt as to the origin of epithelial lining from mucous membrane. I saw no evidence regarding the probable origin of the cartilage, however. In one of the two series referred to above, the anterior end of the tube could be traced through the sphenoid bone to the pharynx where it apparently stopped.

SUMMARY

1. Ciliated epithelium was found to line some portions of the side of the cleft adjacent to the pars anterior but was never found on the opposite side.

2. The so-called 'colloid vesicles' of the cysts of the pars intermedia and occasionally of the pars glandularis are usually lined with ciliated epithelium.

3. From the above two considerations and also from the fact that in the adult guinea pig, the lumen of an apparent cyst can sometimes be found continuous with the lumen of the cleft, the conclusion that these cysts and the cleft have the same origin is justified.

4. No colloid-like substance was found either in the cleft or in the vesicles. Both contained granular substances embedded in what stained and appeared like mucous, and which occasionally contained degenerated epithelial cells. These cells seemed to have broken off from definite regions of the lining.

5. The only substance resembling the colloid of the thyroid gland was found in the pars intermedia and nervosa, especially in the neck of the latter. Also, very often it was found in that portion of the tubercinereum covered by epithelium. This substance occasionally has a granular and hyaline appearance, thus differing from the colloid of the thyroid.

6. Apparently the colloid just described is a secretion of the pars intermedia passing via the pars nervosa into the brain substance, perhaps to be absorbed into the cerebro-spinal fluid.

In concluding I wish to express my thanks to Professor Meyer for his assistance, helpful suggestions and criticisms in the preparation of this paper.

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THE THORACIC DUCT OF THE ADULT GUINEA PIG

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THIRTY-FOUR FIGURES

There are comparatively few reports in the literature covering considerable numbers of thoracic ducts in different animals. Davis ('15) described and pictured the thoracic duct of man in 22 cases, he being the first to describe and picture over 20 thoracic ducts completely in any one animal. McClure and Silvester ('09) described the termination of the thoracic duct in 50 animals of 25 different species and pictured 31 cases. Parsons and Sargent ('09) described the thoracic duct in man, from the middle of the thorax to its venous connection, in 40 cases, Verneuli ('53) described its termination in 24 cases and Wendel in 17 cases in man. Other investigators have reported abnormal cases but the number reported by each individual has been comparatively small, and will be mentioned later.

In this article the author has given the results as he has found them without endeavoring to explain any of the findings from a developmental point of view. The development of the lymphatics of the guinea pig is unknown and in those animals in which it is known it is still a matter of controversy. A personal investigation of its development in the guinea pig was for several reasons impossible.

In the course of the work 34 guinea pigs of adult size (of these 20 or 58.8 per cent were males and 14 or 41.1 per cent were females) were used. Since they were obtained from different sources, they were not in-bred and the chances of any inherited similarity of variation were thus eliminated.

METHOD

Each animal was killed by the use of ordinary illuminating gas. The guinea pig is extremely susceptible to the gas. Each animal was taken from the jar at once and injected immediately with India ink. For injection a 2 cc. hypodermic syringe with a fine needle was used and from 1 to 2 cc. of diluted india ink was injected subcutaneously into the pad of each hind foot. Then pressure was applied to the pad by the hand and the legs worked and massaged. An incision was then made through the skin the whole length of the ventral surface of the trunk in the median line, and from this an incision was made out to each of the four limbs. The skin was then reflected. The abdomino-inguinal lymph nodes were then visible, being partly or completely colored by the india ink. These lymph nodes appeared in groups of three or four on each side. Into these nodes I injected about 0.5 cc. of India ink. The abdomen was then opened by a median incision and a transverse incision. By displacing the intestines two large nodes were visible, one on each side in relation to the iliac blood vessels. These nodes too were already colored with the ink which had passed through them and up into the thoracic duct which showed very distinctly. Into these two large external iliac nodes about 0.5 cc. of ink was injected. I also injected about 1 to 2 cc. of ink into the mesenteric nodes. I first injected the smallest which lie near where the colon joins the small intestine. The ink flowed along a number of channels into several large nodes near the root of the mesentery. By all of these injections a large amount of ink was put into the thoracic duct. I immediately tied off the two internal and two external jugular veins, the subclavian veins, and the superior vena cava, and thus kept the ink from passing into the venous system. The animals were then put into 10 per cent formalin with as little handling as possible and dissected after twenty-four hours or more. Before preservation a preliminary examination was always made for fear of some of the injection fading out. The dissections were performed with the aid of a lens when necessary.

Lewis ('05) in working out the development of the lymphatic system in the rabbit, began with a 21 mm. pig, the species used by Sabin, to test his technique. In order to test or control my technique, I injected a young cat in a similar manner and after it was fixed, dissected it. I found the duct beginning at a large cysterna chyli continuing as a large single duct for some distance. It then divided into two vessels for a distance of several centimeters and again united and joined the left external jugular vein. Davison ('10) describes and pictures a corresponding duct in the cat.

GENERAL RESULTS

The injected ink from the hind foot came to the abdomino-inguinal nodes in several channels. In a number of the cases, the ink would pass into the first node and then on to the next. In many cases some of the ink passed the next abdomino-inguinal node by a vessel running around it and thus passed along faster than that which went through the node. But this shunting never took place in the two large iliac nodes which were large and oval with from one to three afferent lymph vessels entering the distal end and with one and sometimes two efferents. In every case the ink passed with perfect ease through these nodes and up into the lumbar plexus and then into the thoracic duct. It never backed up into the mesenteric nodes.

In nearly every case while injecting the mesenteric nodes about the same time that a node became completely black, the ink would quickly back up all the veins that extend between the node to the intestine. This retrograde injection of the veins happened in every instance in the injection of the large nodes near the root of the mesentery and confirms the observation of Meyer ('14). Baum ('11) has endeavored to explain similar occurrences in other animals. This retrograde injection of the veins never happened with any of the other nodes injected, as the inguinal or external iliac nodes.

In every case the lymphatics from the kidneys which connected with the lymphatic plexus around the abdominal blood vessels where the renal blood vessels come off, were injected

back into the kidney. Between the two kidneys and dorsal to the blood vessels two to three nodes were always present on each side and sometimes also one or two in the mid-line. The nodes on the right side nearly always appeared to be the larger.

THE THORACIC DUCT

The thoracic duct in the guinea pig is not a single but most usually double, consisting of a right and left duct lying at the respective sides of the thoracic aorta. At the beginning of the thoracic duct in the thorax there was in more than half the cases a dilation which will be spoken of later. The thoracic duct arises in the abdomen from a plexus of lymph vessels lying dorsal to the abdominal aorta and the inferior vena cava. A plexus of lymph vessels lying ventral to these vessels connects with the dorsal plexus. The latter may contain several lymph nodes (fig. 12) and is connected with the several intestinal trunks, which join with this plexus and with the nodes on either side of the aorta. Over the ventral surface of the lumbar portion of the inferior vena cava and the aorta there is found a plexus of lymph vessels connecting caudally with the iliac nodes and cranially with the superior lumbar abdominal plexus. This plexus is connected on each side of the blood vessels with the inferior dorsal lumbar plexus. In the figures the ventral plexus of the lumbar region which was rather indistinct has not been shown because it was dissected away but the cut connections with the dorsal lumbar plexus can be seen at x in the figures.

In the thorax a very definite plexus exists between the two ducts. The thoracic plexus which, however, lies wholly dorsal to the aorta usually extends between the 8th and 12th or 13th thoracic vertebra. In a number of cases this thoracic plexus was not continuous with the superior dorsal lumbar plexus, but was joined by one or more channels. In no case was there any vessel that was injected which ran ventral to any part of the thoracic aorta.

The right and left ducts continued on their respective sides of the aorta cranially until at about the 5th to 6th thoracic

vertebra where the right duct passed cranially behind the aorta over to the left side and usually joined the left duct between the 2d to the 1st thoracic vertebra. Before the main union of the right and left ducts, the left passes over the left innominate artery, but under this artery there was usually a cross connection between the two ducts. The united ducts continued behind the left innominate vein and entered it usually at the junction of the internal jugular or between that of the internal and external jugular veins, that is at the jugular angle.

Davis ('15) described nine types of ducts and Lane ('47) three. These classifications depend upon whether the duct is double or single, whether it terminates in the venous system on the left or the right side or on both sides, and in the case of a single duct, upon which side of the aorta it lies, thus making nine types in all. In man, Davis found 6 out of 22 cases, or 27 per cent in type 2, that is, possessing double ducts which unite before terminating on the left side. In the guinea pig I found 30 out of 34 cases (figs. 1 to 34, except 7, 12, 20 and 23) or 88.2 per cent of this type. Lower ('80) and Nuhn ('49) have also described similar thoracic ducts in man. Fleischman has regarded as normal in man, ducts which subdivide into two trunks which are frequently connected. Type VI in which the thoracic duct is single and lies to the right for the most part and later turns to the left between the 3rd and 5th thoracic vertebra and opens into the venous system on the left, is described as normal for man by anatomists. Davis found this type to occur in 63.6 per cent of his cases. In the guinea pig I found 1 case (fig. 12) out of 34 or 2.9 per cent belonging to this type. In type IX in which the thoracic duct runs on the left side for its entire extent and empties into the venous system on the left, Davis described 1 case or 4.5 per cent of his cases. Cameron ('03) also described a similar case in man. In the guinea pig this type occurred in 3 cases (figs. 7, 20 and 23) out of 34 or in 8.8 per cent. In all 3 cases of this type it is interesting to note that the right thoracic duct extended cephalad to about the 9th vertebra, and that the usual plexus between it and the left thoracic duct was present. It ended blindly in only one case (fig. 7), and in the other two

it turned over towards the left. In one of these (fig. 20) it even ran some distance caudally after turning towards the left.

Type I, in which there is a double duct each emptying into the venous system on its respective side, has according to Davis been described by Hommel ('37), Winslow ('66), Cruickshank ('90), Sommering ('92). Such ducts were also described by Krause ('82) but Davis found no such ducts. However, Meyer ('15) found a double duct which may be classed in this type. He described it as follows:

> From it (cisterna chyli) a large left thoracic duct extended cranially and emptied into the subclavian vein after being joined by the left cervical trunk. But in addition to the left thoracic duct a smaller duct ran to the right from the cisterna chyli and then extended cranially parallel to the left duct, continued directly with the left cervical and joined the left thoracic duct by a transverse branch in the bronchial region after receiving a large bronchial trunk. In addition to being double, this specimen of the thoracic duct was interesting in the fact that the right cervical trunk joined the right thoracic trunk in the retro-bronchial region and sent a transverse communicating branch which joined the left thoracic duct after receiving a large bronchial trunk.

I found no cases of this type in the 34 animals examined.

In type III, there are two thoracic ducts which terminate in the right angulus venous. In man Breschet ('36) described one case of this type but I found none in the guinea pig.

In type IV the duct is single and on the right, but bifurcates and joins the venous system on both the right and left sides. Examples of it have been described by Butler ('03), Lauth ('35), von Patruban '(44), Haller ('46), Diemerbroeck ('85) and Cousin ('98), but Davis found no such ducts in his cases and I likewise found none.

Ducts of type V, which consists of a single duct on the left which later divides and enters the venous system of the left and right sides, have not been described for the human being and I found none in the guinea pig.

Type VII, which consists of a single duct on the left which later crosses over to the right and joins the venous system on that side, like type V, likewise has never been described in man. Neither did I find any ducts of these types, nor of type VIII, which

is a single duct on the right side which enters the venous system on that side. Cases of ducts of this type have been described by Todd ('39), Watson ('72), Fife and Haller ('75), Cruickshank ('90), Fleischmann ('15) and Davis ('15).

In the guinea pig, I found only three types—2, 6 and 8—which fall in Davis' classification for man.

In comparing the thoracic duct of the guinea pig with those of other animals, there are some similarities and marked differences. In the dog the thoracic duct may be single throughout, but often divides into two branches which unite in an ampulla. The primitive plexiform arrangement persists in varying degree. In the pig the thoracic duct divides into two ducts which unite to form an ampulla. In the guinea pig in 5 cases (figs. 3, 5, 6, 17 and 30) out of my 34, the duct divided after union of the right and left and joined again before entering the venous system, but there was no well-marked ampulla as described in the dog and pig and in some human cases. In the cat there is but one duct which usually divides in the upper part of the thorax into two or three vessels, which pass along parallel and then unite before the duct enters the left external jugular vein. None of my cases in the guinea pig represent this plan except that shown in figure 23 provided however the short piece of the right thoracic duct and the thoracic plexus had been absent and the dilation above the diaphragm had been in the abdomen just below the diaphragm. In the horse according to Sisson, the thoracic duct takes quite a tortuous course. The duct in the horse is often double thus agreeing with the condition in the guinea pig. In the ox too the duct is rarely ever single, but often double and plexiform. Sala ('99) and Pensa ('08) also picture bilateral symmetrical ducts in birds. Wiedesheim ('07) gives bilateral symmetrical ducts in the chick with a plexus between the lower part and at the root of the mesentery. Schimkewitsch ('10) also pictures bilateral symmetrical ducts in the frog. Huntington ('11) says that the thoracic duct of the cat is potentially bilaterally symmetrical.

Out of the 34 cases in the guinea pig not one had any connection with the right lymphatico-venous communication. In

the 40 cases described by Parsons and Sargent in man, in 18 of the cases, or 45 per cent, the duct divided and this division usually lay behind the left common carotid artery about 5 cm. or less from its termination. The divisions were usually of the same size, but if of unequal size, the upper division was usually the larger. In 3 of these 18 cases of bifurcating ducts, he found that one divided again, forming a kind of plexus, while in 1 of the cases both divisions divided again. In 9 of the 18 cases the 2 ducts united again before reaching the vein and emptied only as one duct. In one they even joined as late as in the wall of the vein, but the others joined before. Job ('15) in 50 rats found no case in which the duct or a branch entered on the right side.

LYMPHATICO-VENOUS COMMUNICATION

Concerning lymphatico-venous communications, much more has been done and reported than on the thoracic duct as a whole. McClure and Silvester ('09) have described the communications in fifty animals covering 25 species and have pictured 31 cases. They have given 9 types of lymphatico-venous communications which greatly facilitates the classification of communications. In speaking of the common jugular district and the jugulo-subclavian districts as points of communication in a large number of cats, they say,

> Neither one of these two districts predominates as the place of communication between the lymphatics and the veins, but either may serve equally in this capacity. If communications are so consistent they should rest upon a morphological interpretation of their development.

In the guinea pig, 33 out of 34 cases or 97 per cent, had single communications. The other one (fig. 6), or 2.9 per cent, had a double communication. As regards the left lymphatico-venous communications, all of my cases come under type 1, in which there are two lymphatico-venous communications on the left side. Even the case (fig. 6) in which there is a double communication belongs here, for in this case both communications are in the common jugular region. There is a predomi-

nance of single over multiple communications at the two usual districts of lymphatico-venous communications. One where the thoracic duct terminates in the common jugular district, and the other where the brachial lymphatics terminate in the jugulo-subclavian district. In the one case in which McClure and Silvester picture the left lymphatico-venous communication in the guinea pig, there is a connection between the termination of the thoracic duct and that of the cervical trunk with that of the termination of the brachial trunk. In several cases a branch from the thoracic duct near its termination, extended brachially, but in no case did I observe a communication. McClure and Silvester have pictured, in the guinea pig, a large cervical lymph node with a lymph vessel several centimeters long connecting with the thoracic duct just before its termination. I found this present in all my animals as shown in figure 3. In a large number of the cases the injected ink passed from the thoracic duct up into this cervical trunk about 2 cm. (fig. 15).

I have arranged several tables from Davis and modified them giving the percentage of the different kinds of termination in man and the guinea pig.

In table 5, the similarity between the guinea pig and man in regard to the large percentage of single terminations will be readily noticed. In the 34 cases examined, only one case (fig. 6) had more than one termination, this being double. Termi-

TABLE 1

Termination of guinea pig (34 cases)

MODE	PLACE OF TERMINATION	CASES	PER CENT	SEE FIGURES
Single.....	Left internal jugulo-sub-clavian junction	15	44.11	1, 2, 4, 5, 9, 10, 11, 12, 13, 14, 16, 17, 18, 27, 32
Single.....	Left jugular angle	13	38.23	3, 7, 15, 19, 20, 21, 22, 24, 28, 29, 30, 33, 34
Single.....	Left internal jugular	2	5.88	26, 31
Single.....	Left external jugular	3	8.82	8, 23, 25
Double.....	1 division subclavian; 1 division at internal jugular and subclavian junction	1	2.94	6

TABLE 2

Parsons and Sargent's 40 human cases. Tables 2, 3, 4, after Davis

MODE	PLACE OF TERMINATION	CASES	PER CENT
Single	Left internal jugular	28	70.00
Single	Left internal jugular	3	7.50
Double	Left internal jugular	4	10.25
Double	Left internal jugular and some other vein	2	5.00
Double	1 branch in left internal jugular: 1 branch in left subclavian	1	2.50
Quadruple	Left internal jugular	1	2.50
Quadruple	1 branch in left internal jugular; 3 branches in left subclavian	1	2.50

TABLE 3

Wendel's 17 human cases termination

MODE	PLACE OF TERMINATION	CASES	PER CENT
Single	Not stated	9	52.94
Double	Not stated	3	17.64
Triple	Not stated	1	5.88
Multiple	Not stated	4	23.52
Boullard's cases reported by Verneuil			
Single	Not stated	18	74.98
Double	Not stated	3	12.49
Triple	Not stated	2	8.33
Sixfold	Not stated	1	4.16

TABLE 4

Davis' 22 human cases

MODE	TERMINATION	CASES	PER CENT
Single	Left angulus venosus	5	22.72
Single	Left subclavian	10	45.4[illegible]
Single	Left internal jugular	1	4.54
Single	Left innominate	1	4.54
Double	1 branch of left internal jugular; 1 branch in angulus venosus	1	4.54
Double	Left subclavian	1	4.54
Triple	2 branches in left internal jugular; 1 branch in left vertebral	1	4.54
Triple	Right internal jugular	1	4.54
Quadruple	Left subclavian	1	4.54

TABLE 5

Man and guinea pig

MODE OF TERMINATION	PARSONS AND SARGENT	BOULLARD	WENDEL	DAVIS	CLATTENBURG GUINEA PIG
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
Single	77.50	74.98	52.94	77.26	97.05
Double	17.50	12.49	17.64	9.09	2.93
Triple		8.33	5.88	9.09	
Quadruple	5.00			4.54	
Multiple			23.52		
Sixfold		4.16			

nations of the thoracic duct on the right side, both of a single and double duct, have been described by a number of authors in man. Absence of the thoracic duct in a new born child has also been reported by Smith ('89).

In the cat the termination of the duct is single at the external jugular near the jugulo-subclavian junction according to Reighard and Jennings ('01). In the dog the termination is in the left brachio-cephalic vein according to Chaveau ('10), while in the pig its termination is near that of the left jugular vein. In the horse according to Sisson ('11) the termination is in the left anterior vena cava behind the jugulars. In the frog and chick in which double ducts occur as in the guinea pig, they are said to terminate in the superior vena cavae making the ducts bilaterally symmetrical.

A number of different authors have described lymphatico-venous communications other than those at the base of the neck. Silvester ('12) described the presence of permanent communications between the lymphatics and venous system at the level of the renal veins in the adult South American monkeys. Job ('15) also described a portal communication and an ilio-lumbar connection besides the renal lymphatico-venous communications in the common rat. Wutzer ('45) in man and Boddaert ('99) in the rabbit have described the termination of the thoracic duct in the azygos vein.

In one case (fig. 3) in the guinea pig, I found a communication which differs from any that I have yet seen described. In

this case there were the two ducts as usual which united between the first and second vertebra. However, just before this union they were connected just below the left innominate artery. Just caudal to this cross connection there was a collateral which ran to the left and cranially from the left duct. This collateral was about half a centimeter in length and connected with a vein. I verified this communication by forcing all the ink out of the collateral and the vein, and then by pressure, forced more ink out through this channel from the left thoracic duct and into the vein. Small masses that passed along could easily be seen through the thin walls of the vessels by the use of a dissecting microscope. The vein with which this communication took place corresponds, as far as concerns the area it drains, to the accessory hemi-azygos but not as to its termination. It terminated in the left innominate vein just medial to the internal jugular vein. I might mention that in the guinea pig the veins corresponding to the azygos and hemi-azygos lie dorsal to the ribs and there is no communications between them, ventral to the vertebra. Huntington ('10) in speaking of connections other than at the common jugular and jugulo-subclavian angles, says that

> Such connections, if they exist in certain forms, must be interpreted with our present knowledge of mammalian lymphatic organization, as retention of other primitive lymph heart bonds between the lymphatic and venous system which, in the greater number of mammalia, are not developed and carried into the typical adult plan, but which may, while a typical for the general class, appear in certain specialized forms. It is possible that the reported instances of the termination of the thoracic duct in one of the azygos veins or its tributaries in the adult human subjects can be interpreted as variations depending for their genesis on the atypical development and retention of a lymphatico-venous heart formation at points other than the ones normally concerned in the production of the jugular lymph sac. The reported cases are, however, not sufficiently authentic to accept them at their face value, and the available evidence is too scanty to warrant the assumption that these variations, if they exist, are of a progressive character tending towards the eventual reduction of the thoracic duct and substitution for the same of a more direct connection of the abdominal lymphatic channels with the venous system.

RECEPTACULUM CHYLI

In man Davis ('15) found the cisterna chyli present in 50 per cent of his cases. The cisterna chyli being usually situated between the 12th thoracic and 2nd lumbar vertebra. In the dog the cisterna chyli is large and fusiform. In the ox the cisterna chyli is small and variable, while in the horse it is rather elongated, measuring about 10 cm. In both the cat and rabbit there is a large and well-defined receptaculum chyli. In all of the mammals mentioned above in which a cisterna chyli exists it is situated in the abdomen, In the guinea pig, I found no abdominal cisterna chyli, but in 73.52 per cent of the cases (table 6) there was a well-marked dilation in the thorax varying in location between the 11th to 13th thoracic vertebra. These dilations if they are to be called cisterna chyli must be designated as thoracic cisterna chyli. Table 6 shows the cases in which the dilations occurred and their relation to the right or left thoracic ducts.

LYMPH NODES

The nodes represented in the figures are those of the abdomino-inguinal, external iliac, mesenteric and cervical regions and those on each side of the superior lumbar plexus. In addition to these, nodes occurred in the dorsal lumbar plexus in a number of cases (figs. 1, 2, 3, etc.). Davis pictured 45 per cent of the ducts connected with thoracic lymph nodes.

According to Sabin ('12) lymph glands develop from a lymphatic plexus and Pensa ('09) states lymph glands may occur along the course of the thoracic duct. Since in the guinea pig there is such a large plexus between the lower half of the two thoracic ducts, one might expect to find lymph nodes here but in no animal were thoracic lymph nodes injected. Moreover, none were observed uninjected in relation to this plexus. In fact, the only lymph nodes noticed in the thorax were the bronchial nodes and a large node or so at the apex of the thorax. McClure and Silvester picture in guinea pigs a channel connecting one of these nodes at the apex of the thoracic cavity, and the right thoracic

TABLE 6

NUMBER	TYPE OF DUCT: Single: Right	TYPE OF DUCT: Single: Left	TYPE OF DUCT: Double	CYSTERNA CHYLI PRESENT: Right	CYSTERNA CHYLI PRESENT: Median	CYSTERNA CHYLI PRESENT: Left	INTERNAL JUGULAR AND INNOMINATE JUNCTION	INNOMINATE BETWEEN JUGULARS	INTERNAL JUGULAR	EXTERNAL JUGULAR INNOMINATE JUNCTION	LOOP AT LEFT 6TH RIB	COMMUNICATION 1ST TO 2ND RIB	SEX: Male	SEX: Female	NUMBER OF RIBS: 13	NUMBER OF RIBS: 12
1			+		+		+					+	+		+	
2			+	+			+					+	+		+	
3			+					+			+		+		+	
4			+		+		+				+			+		+
5			+		+		+					+		+	+	
6		+			+		+	+						+		+
7			+		+									+	+	
8			+							+					+	
9			+			+	+					+	+		+	
10			+			+	+				+		+		+	
11			+				+						+		+	
12	+					+							+		+	
13			+				+					+	+		+	
14			+		+		+					+	+		+	
15			+		+		+	+					+		+	
16			+				+				+		+		+	
17			+			+	+					+	+		+	
18			+				+	+			+		+		+	
19			+					+				+	+		+	
20		+				+		+			+		+		+	
21			+			+		+			+		+		+	
22			+					+			+		+		+	
23		+				+		+		+			+		+	
24			+			+		+			+		+		+	

| | | |

duct. Occasionally some of the nodes in relation with the superior lumbar plexus were double and sometimes like a figure 8 (figs. 1, 3, 6, 8, 13, and 30). Job ('15) also described such nodes in the rat. Job states that in this node the caudal part becomes injected, just as the single nodes of the head, knee, elbow and caudal region do, while the anterior part responds as the intestinal and thoracic nodes. As these double nodes were never revealed until the injection was completed and the animal fixed, I am unable to state the manner of injection in the guinea pig.

CONCLUSION

Hence it appears that the normal thoracic duct is double in the guinea pig and consists of a right and left duct lying at the respective sides of the thoracic aorta for the greater distance. The right duct passes behind the aorta at about the 5th rib, then runs cephalad and joins the left duct before terminating. The termination is generally single and terminates in the region of the junctions of the left jugulars. A thoracic dilation corresponding to a cisterna chyli occurs in 73.52 per cent of this series, just above the diaphragm, about the level of the 12th rib.

As can readily be noted from table 6, there is no apparent difference between any of the important features of the thoracic duct in the male and female. Davis in his 22 cases of man pictures collaterals in the thoracic cavity in every case. In the guinea pig collaterals in the thorax were only present in 5 out of 34 cases or in (figs. 3, 5, 16, 18 and 19), 17.6 per cent. Davis also found in man, a division of the main trunk into two trunks which unite again to form a single trunk, in 59 per cent of his cases. In the guinea pig I found one or more such instances in 25 out of the 34 cases examined or in 73.5 per cent (figs. 1, 2, 4, 13, 15, 17–20, 22–24, 25, 28, 29, 31 and 34). In connection with these 'insula' as Haller is said to have called them, it is interesting to note a loop, which comes under this designation, in 11 cases out of 34 (figs. 4, 10, 16, 18, 20, 22, 24, 25, 28, 31 and 34), at about the level of the 6th rib, and in relation with the left thoracic duct on its left side.

Before the right duct joined the left there was a connection between the two just below the left innominate artery in 61.7 per cent of the cases. In those cases in which there were 12 ribs and a cisterna chyli, the latter was usually situated a little more cephalad than in the other cases. Seven of the 34 guinea pigs, or 20.5 per cent had 12 ribs, while the other had 13 ribs.

In conclusion it affords me much pleasure to thank Professor Meyer for his valuable assistance and the suggestions which made this work possible.

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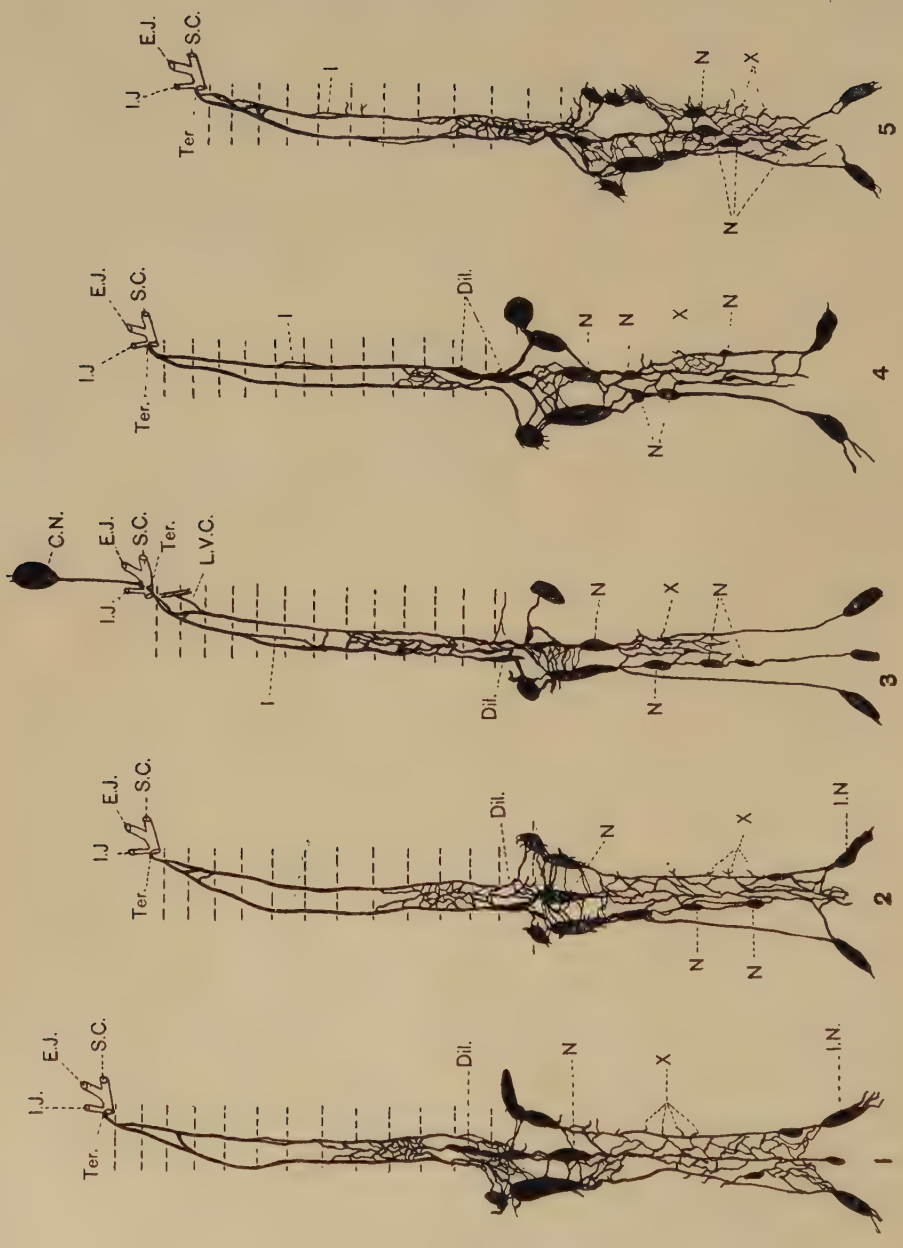
EXPLANATION OF FIGURES

The transverse dotted lines in the figures mark the levels of the ribs. The solid black nodules, unless labelled otherwise, represent lymph nodes.

I. J., internal jugular
E.J., external jugular
S.C., sub-clavian
C.T., cervical trunk
In., innominate vein
X., cut ends of ventral lumbar plexus
L.V.C., lymphatico-venous communication
Ter., indicates termination of thoracic duct
Dil., dilatation of thoracic duct
I., insula
C., Collateral
N., node
I.N., iliac node
C.N., cervical node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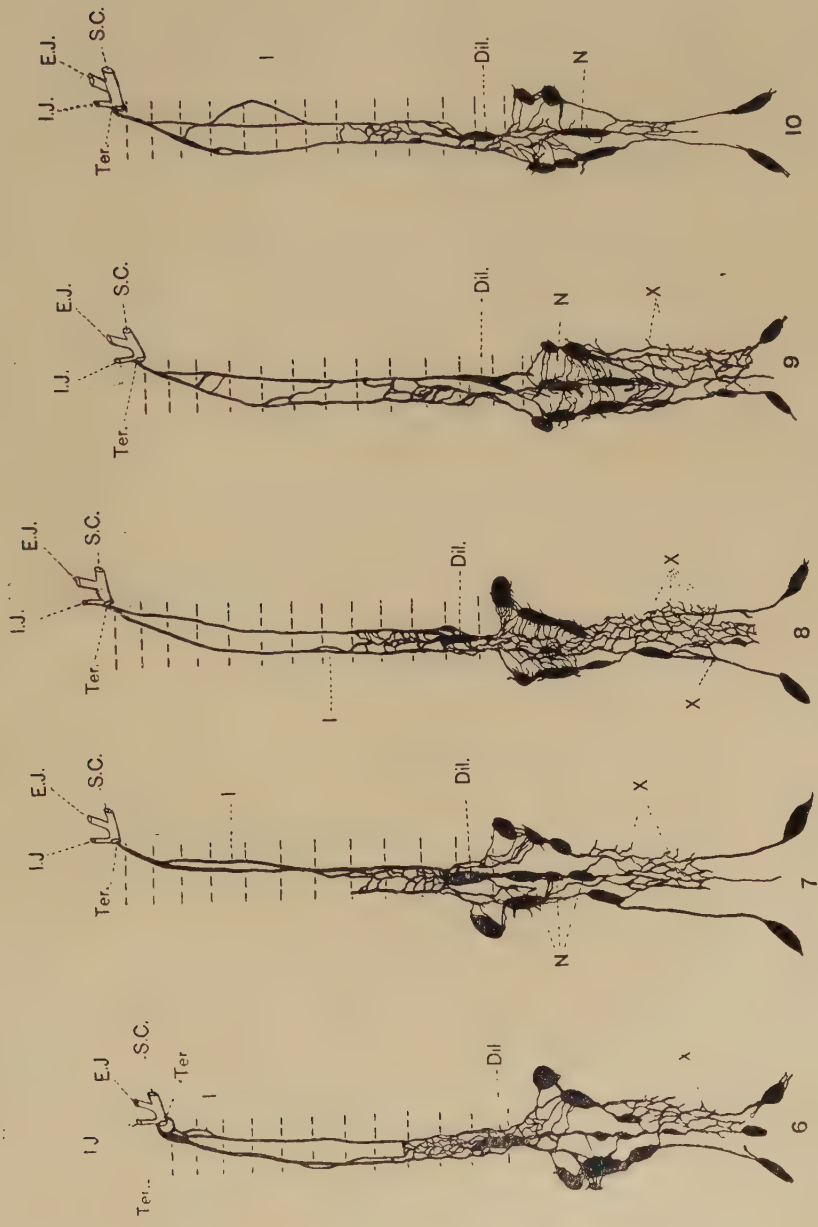
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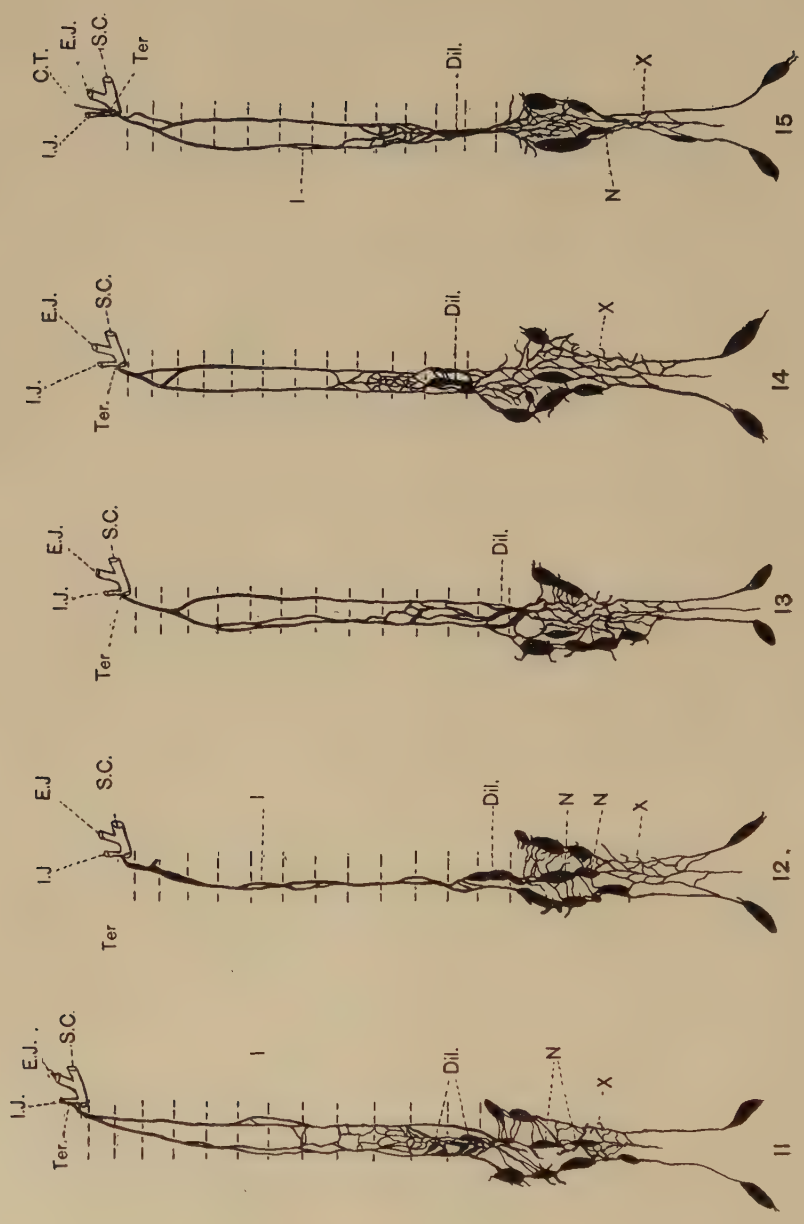
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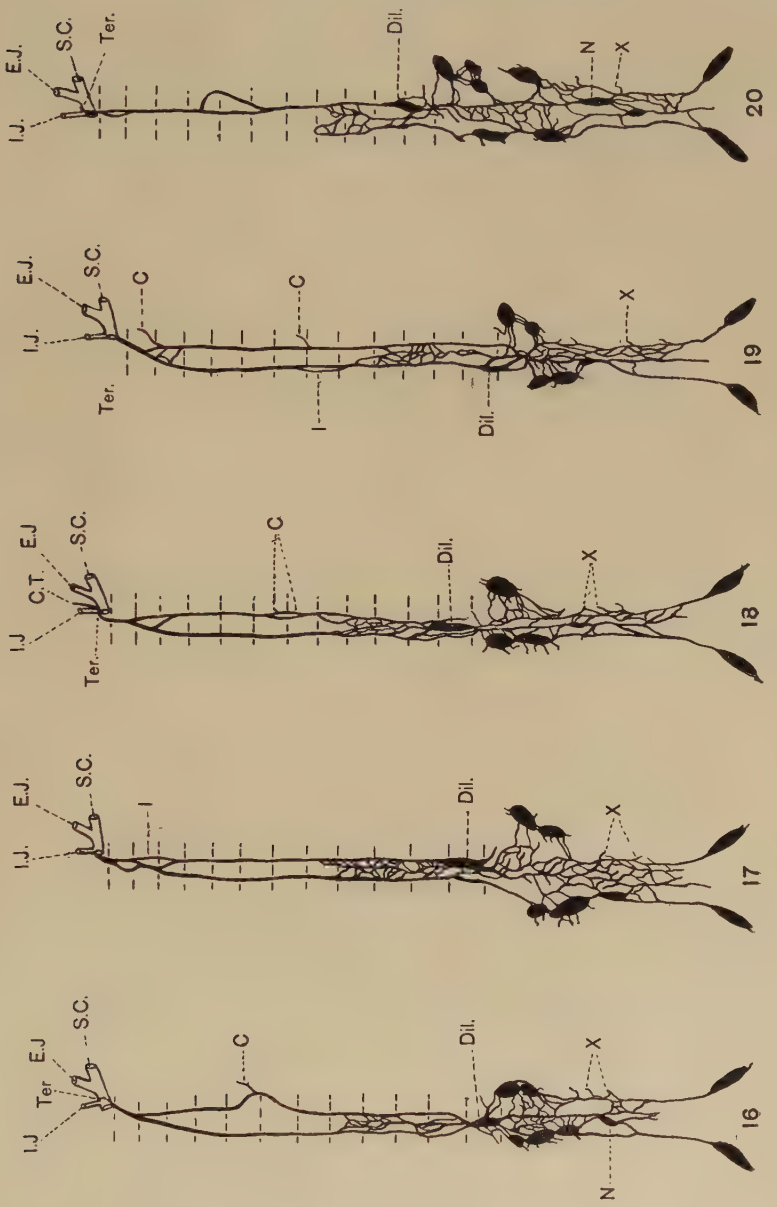
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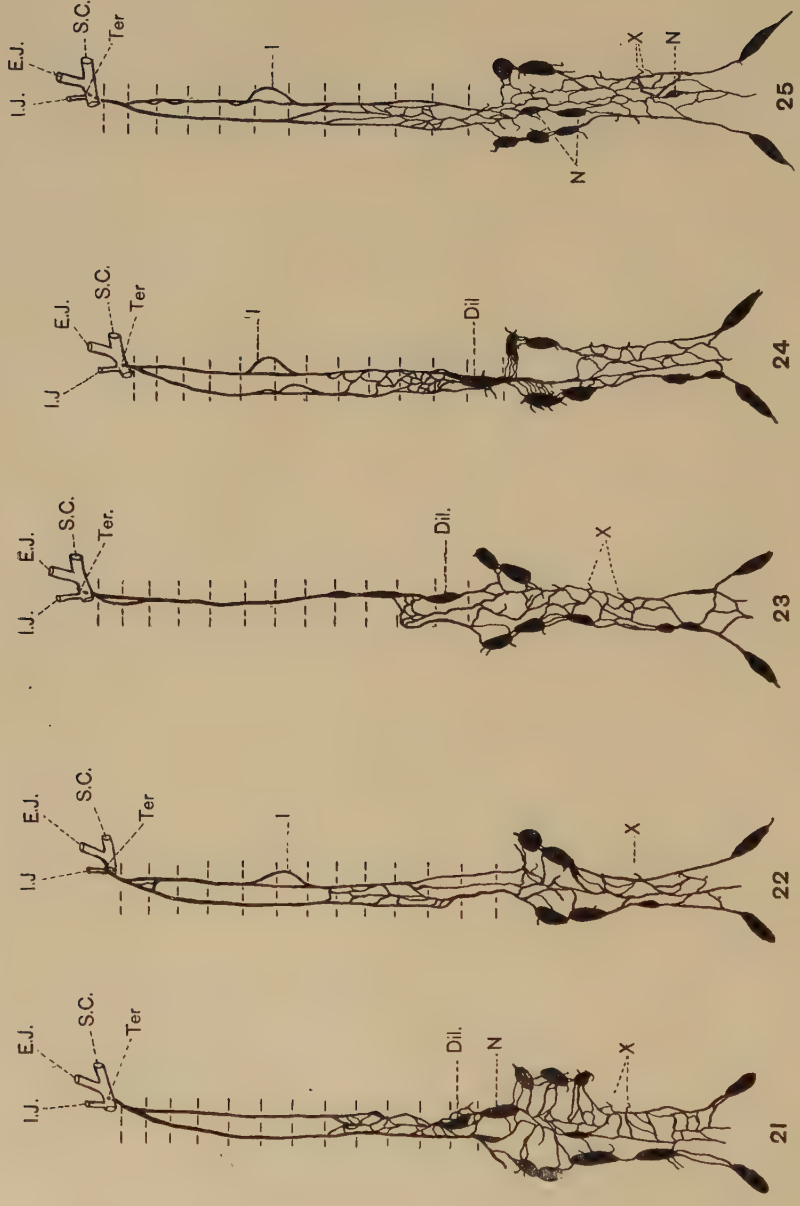
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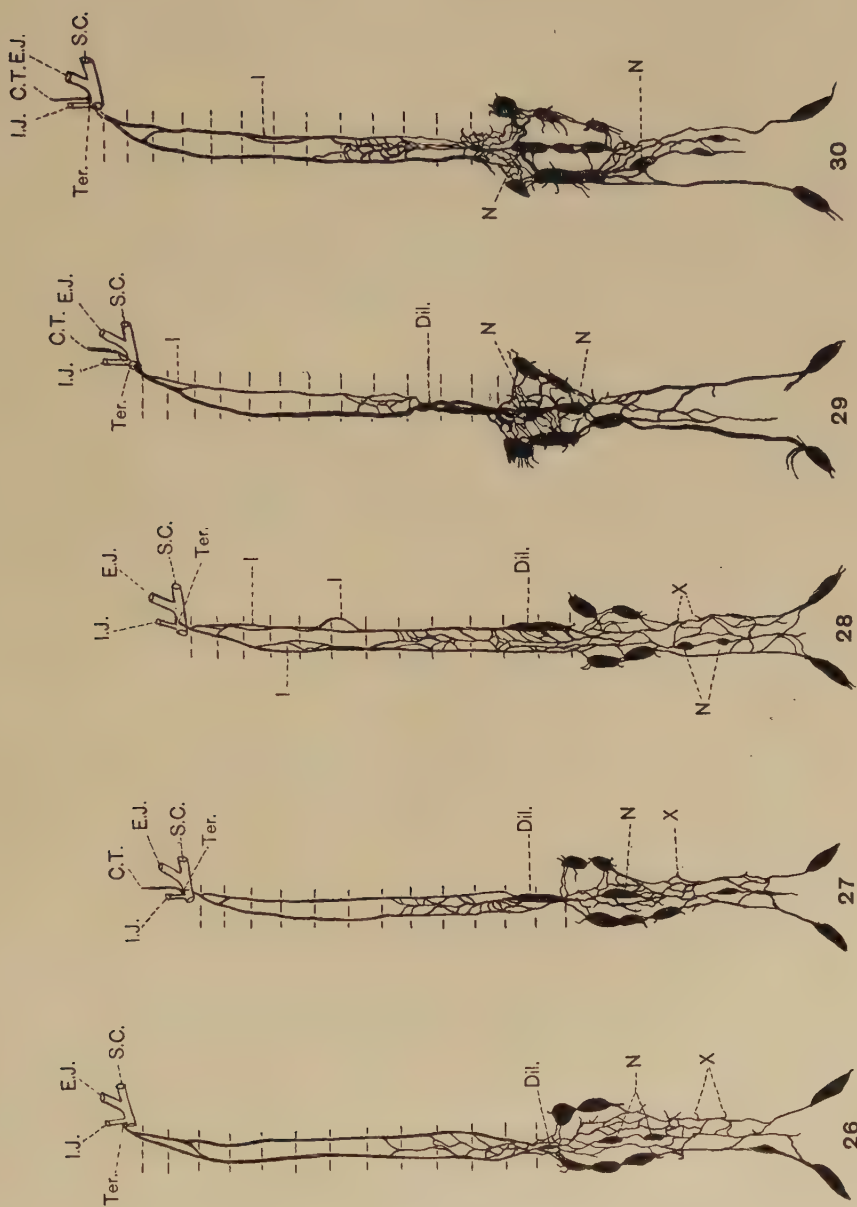
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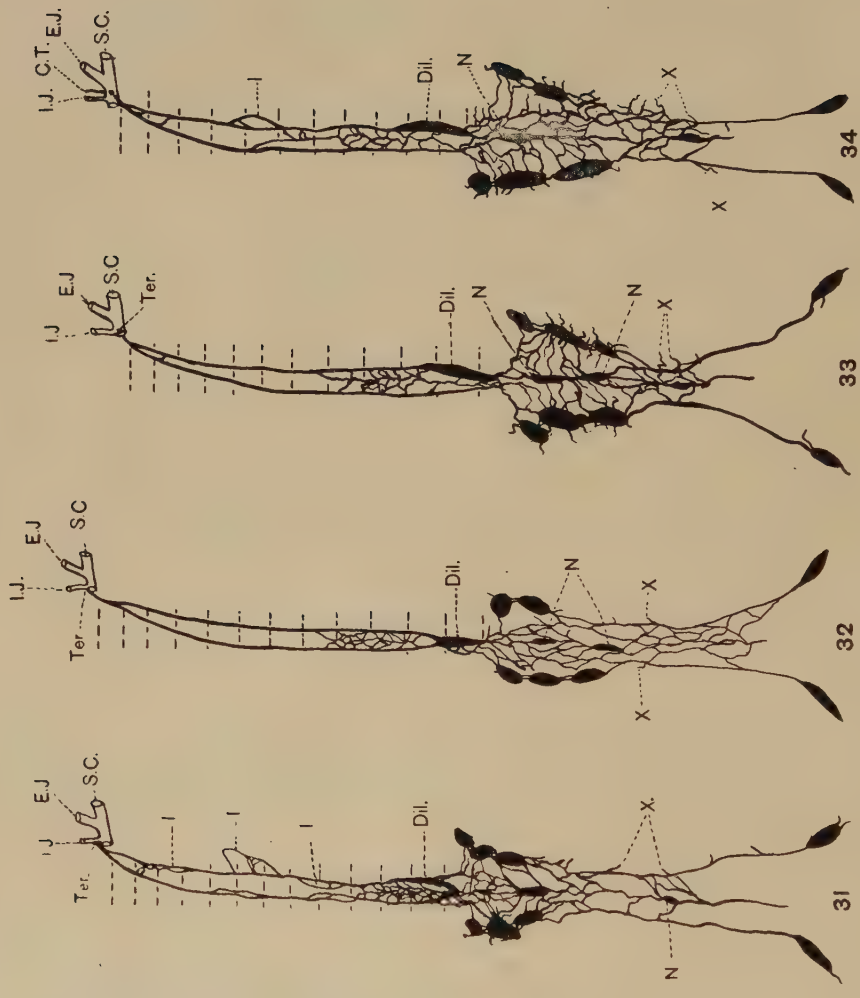
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OBSERVATIONS ON THE SWEAT GLANDS OF TROPICAL AND NORTHERN RACES

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TWO FIGURES

The present preliminary report on the sweat glands was begun as a part of a joint investigation suggested by the late Paul C. Freer, Director of the Bureau of Science of Manila. The general problem was the supposed untoward effect of a tropical residence on the white man and the supposed constitutional adaptability of the dark races to a tropical climate. The investigations were undertaken in a coöperative way by chemists and physicists of the Bureau of Science, the departments of Anatomy, Pharmacology, Physiology and Physics of the University of the Philippines and the United States Army Medical Board for the Study of Tropical Diseases.

Certain claims of Daubler ('00) and Aron ('11) seem to indicate at least one definite adaptation of the dark races to the tropics and lead us to investigate the sweat glands. Daubler states that the size of the sweat glands of the native of tropical Africa is much greater than that of the European. Aron finds that the sweating apparatus of the aborigines of the Philippines, the Negritos, is much superior to that of the white man. This superiority he says is shown by the difference in the manner of sweating rather than in the amount of sweat produced. According to Aron, the Negrito secretes small beads of sweat over the entire body, which soon forms a thin film. As the whole surface of the body is covered by this water film, the maximum cooling effect from evaporation is obtained. In the case of the white man, on the other hand, the sweating is practically limited to certain areas of the body surface. In these areas the sweating

may be quite profuse, but, as most of it drops off, comparatively little cooling effect from evaporation is produced. He suggests that the Negrito has a greater number of sweat glands which are more equally distributed over the entire body.

We have attempted to compare the sweat glands of the tropical races with those of the northern races. Our observations at present scarcely extend beyond a comparison of the number of sweat glands in certain definite skin areas of various races. Similar comparisons of other areas will be made as material is collected. A comparison as to size is an almost endless task as is shown by the work of Huber and Adamson ('03). These investigators have found from measurements of reconstruction a great variation in the size of the sweat glands in the Caucasian. The length of the tubule in the coiled portion of the gland from the plantar region of the foot of an adult was 4.25 mm. A gland from the hairy portion of the pubic region of a woman was found to measure 10.4 mm. They have further shown, and we have confirmed their findings, that it is almost impossible to determine with any degree of accuracy the size of sweat glands without making reconstructions of them. It is even

> now and then exceedingly difficult in a series of sections to trace with certainty a single gland, especially toward the beginning and end of a series of sections of any one gland. Loops of neighboring glands are often in close proximity and are apparently surrounded by a common layer of somewhat denser connective tissue so that a separation of tubules belonging to two, or now and then even three, contiguous glands can be made with certainty only by reconstruction.

In maceration preparations of skin from the palmar region and from the chest in both American and Filipino we have noted a great variation in the size of the glands in each piece of skin taken. Frequently a given gland was fully twice as large as its neighbor. It is thus apparent that a racial comparison of sweat glands as to size to be of any pretence to accuracy must be based upon measurements of a vast number of glands in different portions of the skin of the several races.

TECHNIQUE

In our study of the number and distribution of the sweat glands we find that there is less variation in those occurring on the plantar surface of the foot and the palmar surface of the hand than in other regions of the body. The sweat glands first make their appearance in the embryo in these regions. These areas also lend themselves readily to an extensive enumeration of the sweat glands. Our observations so far have been made principally on these regions. In a warm climate prints of the fingers, palms, toes and plantar surfaces of the feet can be made which in many cases will give a negative impression of every gland duct in the area printed. We have employed the method which is in use in the recruiting office of the United States Army. A very thin layer of the best printer's ink is rolled out with a small hand roller upon a glass plate. The subject's finger (hand or toe, etc.) is carefully and lightly pressed first upon the ink, and next upon a special type of glazed paper. The impressions, when made under suitable conditions, are remarkably clear and the duct of every sweat gland can usually be accounted for. Skin with much cornified epithelium will not make a satisfactory print unless pains are taken to macerate with a dilute caustic and scrape off the surface tissue.

The gland ducts may be counted directly upon the hands and feet with the aid of a good hand lens of about 12 diameters magnification. This is facilitated by first rubbing a little powdered graphite upon the surface of the skin to be examined. This method is far more tedious and has been used only as a check upon the print method. The print method is obviously not adapted to those areas of skin where hair and wrinkles occur. As the ducts of sweat glands frequently open into hair follicles the glands can not be counted by direct inspection. Here we have resorted to maceration methods and to stained sections of skin cut parallel to the surface. The latter method was used by Krause in his study of the number of sweat glands in the skin of the various regions of the body.

Fig. 1 Photograph of a finger print of the distal phalanx of the fourth finger (left) of an American white soldier. × 6.5

Fig. 2 Drawing of a finger print to show orifices of sweat gland ducts. × 10.

Through the courtesy of the surgeon-general's office United States Army and of the office of the chief surgeon, Philippien Division of the United States Army we have had the opportunity of examining finger prints of 300 American white soldiers, 200

American negro soldiers, 150 Filipino (Christian) soldiers and 100 Moro scouts. In addition we have ourselves made many prints of fingers, toes, palms and plantar surfaces of the feet of Americans, Filipinos, Igarotes, Negritos and Hindoos.

In counting sweat glands a glass slide with a graduated square (0.5 cm. each way) was placed over the print, graduated surface down, and the specimen magnified 10 diameters. In good prints, as stated above, every sweat duct can be counted (fig. 1). The graduated square was always placed over the print of the distal phalanx in counting the glands of the fingers, and over that area where the cristae cutis form a whorl or delta.

RACIAL VARIATION IN SWEAT GLANDS

We have counted 248,998 sweat glands in $\frac{1}{4}$ square centimeter areas of 1,572 fingers and 38,736 in the palms, toes and plantar surfaces of the feet. Table 1 shows the average counts per square centimeter of skin area for the various races. Rather uniform variations have been observed in the distribution of sweat glands in the fingers. The number of glands varies in different areas of the volar surfaces of the fingers. The number is greatest near the distal ends and smallest in the immediate region of the flexion groove at the joints. As stated above, the

TABLE 1

Average number of sweat glands per square centimeter of skin area in the various races as shown by fingers

NATIONALITY	FINGERS OF LEFT HAND				FINGERS OF RIGHT HAND				INDIVIDUAL AVERAGE
	5th	4th	3rd	Index	Index	3rd	4th	5th	
American (white)	569.6	600.4	564.4	511.2	519.2	546.4	590.4	552.4	558.2
American (negro)	605.2	634.4	586.0	576.6	561.6	590.4	631.2	594.8	597.2
Filipino	652.0	691.2	653.6	618.4	610.4	630.4	692.8	637.2	653.6
Moro	674.4	755.2	682.8	650.8	651.2	665.2	725.6	640.8	684.4
Negrito (adult)	670.4	752.0	718.8	682.4	666.0	720.0	736.8	701.6	709.2
Hindu	722.0	813.6	744.0	657.6	650.0	737.6	782.0	738.4	738.2
Negrito (youth)	1010.0	996.0	942.8	942.0	865.2	961.2	982.8	881.2	950.0
Average per finger	707.67	749.9	696.3	661.4	646.2	693.0	734.5	678.0	
General average									698.5

number is most nearly constant in the region of the whorl or delta than in other regions. Comparatively few prints of the thumb have been examined. In all of these, however, the number of sweat glands has been distinctly lower than in any of the other fingers. Of the other fingers the second or index finger has shown the lowest average number of glands per unit of skin area, while the fourth or ring finger has shown by far the greatest number of glands. A more detailed comparison of the number of sweat glands per square centimeter of skin for the different fingers in the several races is given below in table 1. The average number of glands per square centimeter of skin area for the finger for all the races examined is 624.4.[1] The greatest number was found in prints of the fingers of Negrito children. It was found that the number of glands per unit of skin area for the hands, feet and toes bears a rather close racial relation to the number on the fingers, and in the different individuals varies directly with the number on the fingers. As regards the different races our results show a greater number of sweat glands in all the tropical than in the northern races.

Taking the American white soldier as the standard, the number of sweat glands per unit of skin area was found to be 6.83 per cent greater in the American negro soldier, 16.61 per cent greater in the Filipino soldier, 22.34 per cent greater in the Moro soldier, 26.81 per cent greater in the adult Negritos, 31.72 per cent greater in the Hindu and 69.82 per cent greater in the Negrito youths and children. Additional details of these counts will be found in table 1. The greater number of sweat glands per unit area with the Negrito youth and child is no doubt due to a corresponding difference in size of the individuals. As all the sweat glands are fully formed at birth[2] it is merely a

[1] This average is much lower than the estimation of earlier authors, thus—"Über die Menge der Knäueldrüsen haben wir ältere Angaben von Krause senior denen zufolge ihre Zahl zwischen 400–600 (Rücken, Wange, erste zwei Abschnitte der unteren Extremitaten) und 2600–2736 auf I □″ Haut schwankt und die grösseren Zahlen an der hanffläche und Fussohle sich finden. Neure Zählungen von Hörschelmann ergeben viel näher stehende Grenzzahlen von 641 Fussrucken, und IIII (vola manus) auf I □ cm und viel mehr drüsen."—Koelliker.

[2] At the fourth month according to Wilder ('16).

question of the increase in skin area during growth bringing about a dispersion of the glands. The ratio of the number of sweat glands in the American white soldier (100 per cent) to that of the Filipino soldier (116.93 per cent) and the Negrito adult (124.05 per cent) shows a wider variation than the differences in size[3] of the individuals of these respective groups. The American negro soldier is of the same approximate size as the American white soldier, and there are 6.83 per cent more sweat glands per unit of skin area in the former. The Hindus examined were of a larger average size[4] than the American soldiers and showed the highest sweat gland count for adults (131.76 per cent). Thus racial variation in size does not account for the difference in ratio of the sweat glands per unit of skin area.

The number of sweat glands was determined in a similar manner from prints of the palmar surface of the hand and the plantar surface of the feet of Americans (white) and Filipinos. Successful prints were made from these areas of 6 American university men and 6 Filipino students; 325 separate areas were counted, giving a total of 38,736 glands. The average number of sweat glands on the palmar surface was 438.0 per square centimeter in the American, and 473.6 in the Filipino. On the plantar surface of the feet there were 436.4 glands per square centimeter in the American and 498.4 in the Filipino. On the plantar surfaces of the toes there was an average of 527 and 525.5 sweat glands per square centimeter in the American and Filipino respectively. Thus the number of sweat glands in the Filipino was in this series 8.1 per cent greater on the palm and 14.1 per cent greater on the plantar surface of the feet than in corresponding areas in the American. In all these counts there was very little individual variation. Different individuals of the same group gave almost the same count.

[3] Captain Davis of the recruiting office of the United States Army in Manila tells us the average weight of the American white soldier is approximately 150 pounds and of the Filipino scout approximately 130 pounds. The Negritos are smaller and can be estimated at about 120 pounds.

[4] All these Hindoos were tall, large and portly and averaged 160–165 pounds in weight.

We are not able to confirm Aron's observation that the tropical aborigines secrete only small beads of sweat over the entire body. On two tramping expeditions in the mountains of the Philippines which we were fortunate enough to arrange with a number of Negritos we observed streams of sweat running down the back, and copious sweating on scalp, forehead and face and sweat dripping from the chin. When making finger prints in camp it was necessary repeatedly to dry off droplets of sweat from the fingers of the Negritos.

From the few maceration preparations mentioned above we are not able to discern any difference in the size of the sweat glands of the American and the Filipino.

As regards number, all our observations show a higher count in all the tropical races. These counts, furthermore, were made on those areas in which the number of sweat glands is the most nearly constant.

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THE RELATIONS OF THE SUPERFICIAL AND DEEP LOBES OF THE PAROTID GLAND TO THE DUCTS AND TO THE FACIAL NERVE

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TWO FIGURES

The parotid gland is described by the current English, French and German text-books of anatomy as essentially a single mass, with various projections, occupying the retro-mandibular fossa and perforated by the facial nerve and its branches.

According to Grégoire ('12), Luschka recognized the division of the parotid into two portions. He quotes Luschka as follows: "Le nerf facial et ses rameaux divisent incomplètement la gland en deux portions, l'une interne plus petite, l'autre externe plus volumineuse." Grégoire cites no reference for this statement, however, nor could I find any mention of it in Luschka's text-book of anatomy ('62 and '67).

Henle ('73), however, in describing the parotid states: "Durch den Stamm und die Hauptverästelungen des N. facialis wird sie unvollkommen in eine mächtigere äussere und eine schwächere innere Schichte abgetheilt." A similar brief statement appears in the more recent edition by Henle-Merkel ('01).

This relation was confirmed by Grégoire upon careful dissections in the human (adult and fetal) and some of the mammalian species, the monkey and the rabbit. In the guinea pig and (usually) in the dog he found the facial nerve lying entirely beneath the parotid gland. In all of these cases Grégoire described the parotid as being divided into a superficial and a deep lobe with the facial nerve and its branches lying between them, except in the dog and guinea pig. He asserted that the two parotid lobes are united at their upper extremities and that this relation results from the mode of development of the gland.

In a human fetus of three months (8 cm.) he observed the parotid gland to be entirely superficial to the facial nerve. But he found the beginning of the deep lobe in a fetus of six or seven months, and concluded that further growth of the gland upward is prevented on reaching the base of the skull and that the growing extremity is apparently deflected inward and downward internal to the facial nerve to form the deep lobe.

Corresponding to this mode of origin Grégoire described the duct from the deep lobe as passing upward and outward, above the branches of the facial nerve to unite with the duct from the superficial lobe.

Since the topography of the parotid gland and the facial nerve is of great importance (especially in surgery), a further investigation of this region was undertaken at the suggestion of Prof. C. M. Jackson, to whom, as well as to Prof. R. E. Scammon, I am indebted for assistance.

I have made careful dissections of sixty-six adult human parotids (from thirty-nine male cadavers), and of thirteen parotids in the human fetus and newborn (total length 36 cm. to 54 cm.). The more important results will be stated briefly.

The human parotid gland (late fetal and adult) consists of a large superficial lobe and a smaller deep lobe (figs. 1 and 2), which are usually readily separable with the exception of a small isthmus where they are more intimately connected.

The connecting isthmus is somewhat variable in size and position, and rarely absent. It is not at the upper extremity of the gland (where a union of the two lobes is described by Grégoire), but somewhat lower, usually located near the middle or the junction of the middle and upper thirds of the gland, and somewhat posteriorly. The isthmus, except in eight of the sixty-six adult cases, consists of gland parenchyma, together with connective tissue, including vessels, and ducts of variable size and number.

The ducts of the parotid are exceedingly variable in their relations and do not conform to the type described by Grégoire. The main parotid (Stenson's) duct may be more closely associated with the superficial lobe (31 of 64 adult cases observed),

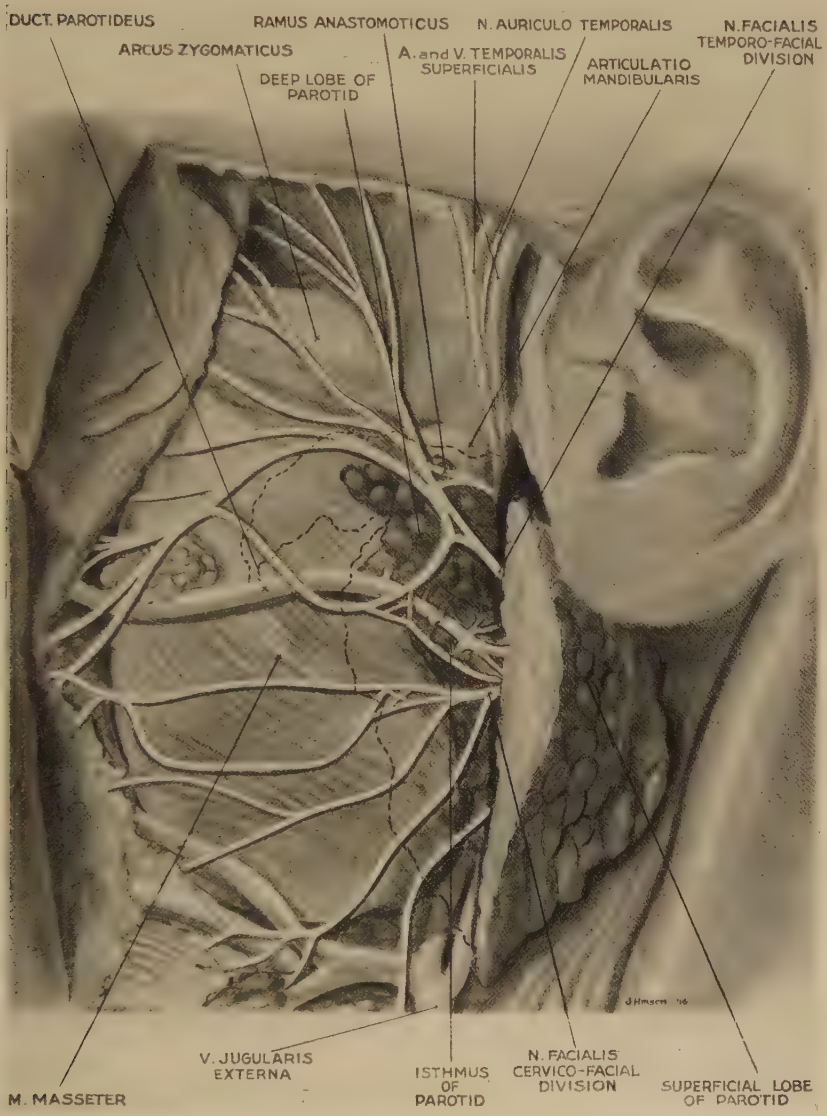

Fig. 1 Lateral view of parotid region dissected to show the relations of the superficial and the deep lobe of the parotid to the duct and to the facial nerve. The anterior portion of the superficial lobe has been removed. Its original outline is indicated by the dotted line. A small accessory lobe is shown on the anterior part of the parotid duct.

or with the deep lobe (16 of 64 cases), or may proceed between the lobes toward the region of the isthmus without intimate relation to either lobe. The main duct branches at a variable distance from the anterior border of the gland, and frequently not until reaching the region of the isthmus. The duct branches

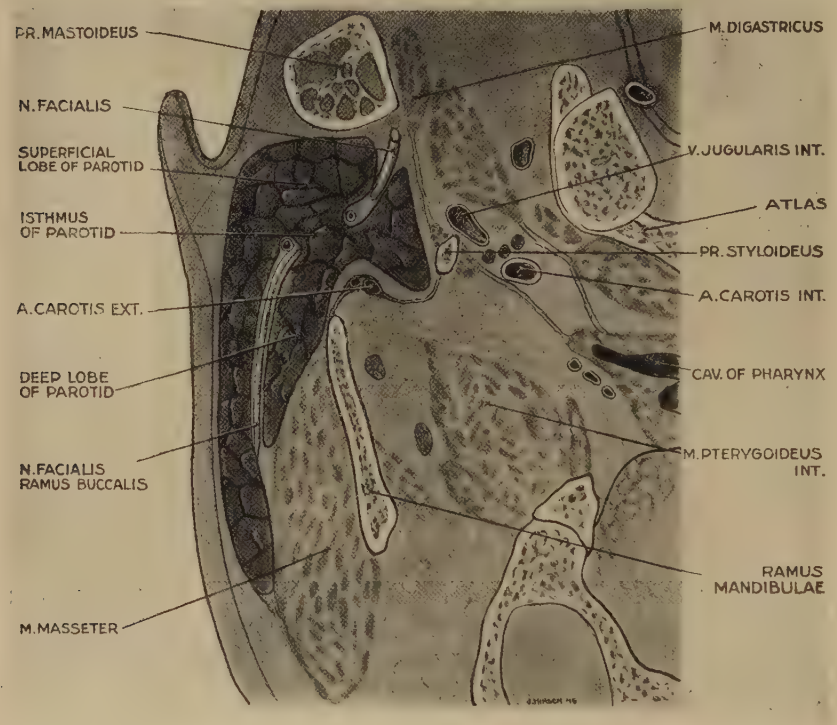

Fig. 2 Horizontal section of the head in the parotid region (semidiagrammatic) to show the relations of the superficial and the deep lobe of the parotid. The two lobes are shown separated by branches of the facial nerve, except in the region of the isthmus.

in a variable manner. Each lobe has usually a main terminal duct, which, however, sometimes receives minor branches from the other lobe. A duct draining part (or exceptionally all) of either the superficial or the deep lobe may cross the isthmus to join the duct of the opposite lobe. Small branches from either

(especially the superficial) lobe may also join the main parotid (Stenson's) duct (fig. 1).

The facial nerve trunk and its main branches lie between the superficial and the deep lobe of the parotid gland (figs. 1 and 2). These lobes are not united at their upper extremities (Λ-shaped), however, with all the nerve branches below the junction of the lobes, as described by Grégoire. The two lobes are united rather in H-shape, the connecting isthmus corresponding to the cross-bar (fig. 2). Upon approaching the isthmus of the gland from behind, the facial nerve divides into its upper (temporo-facial) division, which passes forward above the isthmus, and its lower (cervico-facial) division, which passes below the isthmus (fig. 1). The uppermost and lowermost facial branches may not come into contact with the deep lobe (on account of its small size), though still under cover of the superficial lobe of the parotid. The facial branches lie between the two lobes, sometimes infolded in grooves on the opposing surfaces. Rarely are they entirely surrounded by the gland parenchyma. In the neighborhood of the ducts, the nerve branches lie superficial to those ducts more closely associated with the deep lobe and beneath (internal to) those ducts more closely associated with the superficial lobe. Thus the relations of nerves and ducts are quite variable; but in no case were all of the ducts from the deep lobe observed to pass upward and outward, above all the facial nerve branches, as described by Grégoire. The relations found are therefore not in agreement with Grégoire's theory of the development of the parotid lobes.

In general, since the relations found in the dissections of the late fetus and newborn were essentially similar to those above mentioned for the adult, no separate description of the former is necessary. In one full term fetus of 50 cm., the two lobes were nearly equal in size, but the deep lobe was usually found to be much the smaller. It should be noted, however, that no observations were made upon younger fetuses, to determine the developmental relations.

In conclusion, the results of my investigation may be summarized briefly, as follows: The human parotid gland (late

fetal, newborn and adult) consists of a larger superficial and a smaller deep lobe, usually distinct and readily separable, with separate ducts. The facial nerve and branches lie between these lobes. The lobes are usually joined (not at their upper ends but lower down) by an isthmus separating the temporo-facial and the cervico-facial divisions of the facial nerve. The relations found are not in agreement with Grégoire's theory of the development of the parotid lobes.

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FURTHER OBSERVATIONS ON TAILLESSNESS IN THE RAT

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THREE FIGURES

This paper has three objects: first, to describe skeletal conditions in the region posterior to the lumbar vertebrae of two tailless rats which have appeared in the colony since the writing of the preceding paper (Conrow '15, Anat. Rec., vol. 9, no. 10, p. 777); second, to describe skeletal conditions in the same region of four rats whose tails were removed by operation soon after birth; and third, to emphasize, by a comparison of the skeletal conditions in these two sets of rats, the conclusion of the previous paper, namely, that taillessness in the rat is due not to accident after birth but to a congential defect in the vertebral column.

Since the writing of the previous paper (Conrow '15) four tailless rats have appeared among the standard rats (Mus norvegicus albinus) of the Wistar Institute Colony, making nine tailless specimens observed during the past ten years in a total of 71,500 rats. Of these four, two are at present mated in the colony, and two (a male and a female) have been examined and will be described here. The data concerning these latter are presented in table 1.

In rat No. 4, a male, the vertebrae and pelvic girdle were studied. All vertebrae caudal to the second sacral were lacking, as was a large part of the second sacral. The first sacral was somewhat deformed and had what remained of the second fused with it. Its points of attachment to the pelvic girdle were a little more caudal than usual. (Two of the cervical vertebrae also were partly fused.) The striking feature in this rat was that

TABLE 1

Data on tailless rats

RAT NO.	SPECIES	SEX	AGE	BODY WEIGHT	BODY LENGTH	DATE OF KILLING
			days	*grams*	*mm.*	
4	Mus norvegicus albinus. Standard strain.	M.	about 244	144.4 (wet)	not taken	September 13, 1915
5	Mus norvegicus albinus. Standard strain.	F.	361	133.8	185	August 3, 1916

the vertebral column terminated far from the posterior end of the body, even anterior to the middle of the long axis of the pelvic girdle.

In rat No. 5, a female, the four sacral vertebrae were present but they were more crowded together and fused than is usually the case. There was also one deformed cauda vertebra; the rest were lacking. This rat might not be called strictly tailless,

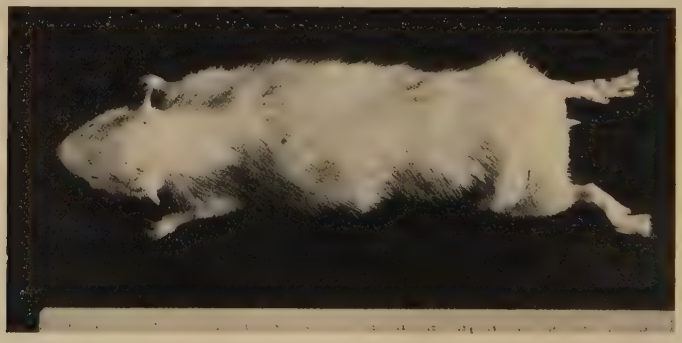

Fig. 1 Congenitally tailless rat, No. 5

since tailless, as previously defined, means "with no caudal vertebrae," but the vertebral column ended several millimeters anterior to the posterior ends of the pelvic girdle. There was an odd, external structure found here just dorsal to the anus, in the position which normally would have been held by the tail. It was a fleshy papilla 11 mm. long and 2.5 mm. in diameter, with the characteristic scaly tail covering. This structure may be seen in figure 1.

The conditions found in these two tailless rats are then (with the exception of the fleshy papilla just mentioned) similar to those found in the tailless rats previously studied.

The experiment of removing by operation the tails of several rats was conducted as follows. Two litters of standard albino new born rats were chosen. In one litter the tails were cut off as close as possible to the origin. In the other litter a slender silk thread was tightly tied about the tail of each rat at the same place. The tails of the first litter healed quickly; the tails of the second litter dropped off in a few days with apparently no inconvenience to the animals. Both litters grew normally and their eyes opened at the usual time—at the end of fifteen days. All were allowed to live, and when nearly a year old, four animals (a male and a female from each litter) were killed and examined. The data concerning them are presented in table 2.

TABLE 2

Data on rats tailless by operation

RAT NO.	SPECIES	SEX	AGE	BODY WEIGHT	BODY LENGTH	DATE OF KILLING
			days	*grams*	*mm.*	
Tails cut 1	Mus norvegicus albinus. Standard strain	M.	271	161.8	not taken	April 20, 1916
Tails cut 2		F.	289	167.4	195	May 8, 1916
Tails tied 1	Mus norvegicus albinus. Standard strain	M.	310	288.0	220	May 1, 1916
Tails tied 2		F.	317	194.2	197	May 8, 1916

Only changes in the caudal vertebrae need be mentioned here since all the sacral vertebrae of the four rats were present and normal.

Of the two rats with tails cut, rat No. 1, a male, had the first four caudal vertebrae and about half of the fifth remaining. Rat No. 2, a female, had the first three caudal vertebrae and about half of the fourth remaining. The appearance of the most posterior vertebrae of this rat and their relation to the pelvic girdle may be seen in figure 2.

Of the two rats with tails tied, rat No. 1, a male, had the first four and about half of the fifth caudal vertebra; while rat

No. 2, a female, also had the first four and a part of the fifth caudal vertebra. The appearance of the most posterior vertebrae of this last rat and their relation to the pelvic girdle may be seen in figure 3.

In each of these four rats the vertebral column extended to the posterior end of the body and all of the caudal vertebrae present were normal, except the fraction of the vertebra actually cut or tied and this showed only slight deformity.

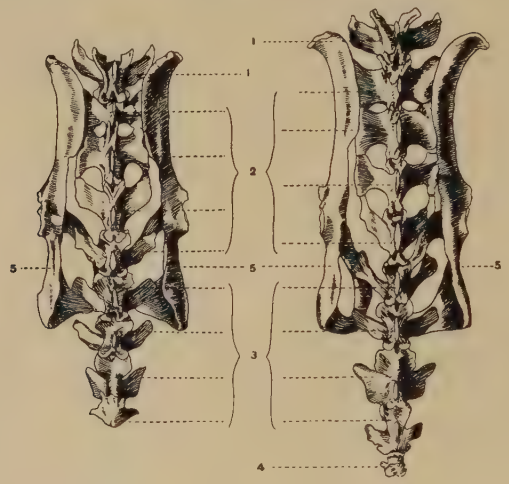

Fig. 2 Tail cut rat No. 2, dorsal aspect; *1*, sixth lumbar vertebra; *2*, four sacral vertebrae; *3*, first four caudal vertebrae; *5*, pelvic girdle.

Fig. 3 Tail tied rat No. 2, dorsal aspect; *1*, sixth lumbar vertebra; *2*, four sacral vertebrae; *3*, first four caudal vertebrae; *4*, fifth caudal vertebra; *5*, pelvic girdle.

A comparison of the vertebral conditions in the congenitally tailless rats and in those rendered tailless by operation gave a marked contrast. In the former the vertebral column ended in the pelvic region, far anterior to the posterior end of the body, and also the terminal vertebrae were more or less deformed and fused; in the latter the vertebral column extended to the posterior end of the body and the vertebrae retained their normal size and shape, except those cut or tied, and even they showed only slight modification.

Since in the experiment the tails were severed as close to the body as possible, and since the vertebrae anterior to the severance not only did not disappear but kept their normal form, it is apparent that the removal of a rat's tail by operation soon after birth does not cause the disappearance of any of the remaining vertebrae, nor does it give rise to deformity or fusion among them. In other words it does not produce such a condition of the vertebrae as is found among rats born tailless, therefore taillessness in the rat as defined is due not to accident but to a congenital defect of the vertebral column.

While this paper was passing through the press, one of the two rats spoken of (p. 155) as mated in the Wistar Institute colony was killed and examined, and also two new tailless rats appeared in the colony, making a total of eleven tailless rats observed to date. The rat examined was killed on December 14, 1916. It was a female of standard strain (Mus norvegicus albinus); its age was 273 days, body weight 168.5 grams, and body length 193 mm. The four sacral vertebrae were present, the third and fourth being slightly deformed. There was also one deformed caudal vertebra and the rudiment of a second. The vertebral column ended far anterior to the posterior ends of the pelvic girdle. The other mated rat (a male) that was not examined is of the inbred albino strain, the 22nd generation.

The two new tailless rats (a female and a male) appeared in Dr. King's strain of small-eyed rats and the left eye of the female is small. The vertebral columns of these three rats all end anterior to the posterior ends of the pelvic girdle, for this condition may be felt distinctly by pressing the finger on the rats' backs in the pelvic girdle region.

THE SIGNIFICANCE OF THE LUNULA OF THE NAIL

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TWO FIGURES

A structure, the significance of which has always been described by a series of different answers in modern text-books of anatomy is the nail lunula. This is a small sharply circumscribed opaque area which is visible near the root of the nail of many individuals. Toldt assumed that the greater opacity of this region is due to the fact that the nail is covered here by a layer of matrix, the cells of which are undergoing active division. Unna expressed the opinion that the opacity is conditioned by the existence in this region of keratohyaline (onychogenic substance). Ranvier has given a similar explanation (quoted from Poirier and Charpy, Traité d'anat. hum., Paris, 1901). He ascribed it to the existence of onychogenic granules which fill the cells of the rete mucosum. V. Brunn, on the other hand, ascribed it to the fibrous structure of the cells undergoing keratinisation in this region of the nail.

Although these particular explanations have for a long time appeared to be inadequate, it is of interest that no one, so far as the author has been able to determine, has attempted to study more carefully the peculiarities in the structure of this region. The fact that the lunula is marked off sharply from the remaining portion of the nail is a direct argument against several of the above explanations. Again, the large number of nails which one sees removed in the dispensary do not show that portion of the nail corresponding to the lunula more opaque than surrounding parts.

During the last few months a careful study of the structure of the nail and its environment has been undertaken for the

purpose of establishing, if possible, some of those conditions which regulate its continuous growth throughout the life of the individual. This study has been planned to include not only a careful investigation of the morphology, histology, and the development of the nail but also a detailed study of its connective support and vascular supply as far as they apply to the solution of the problem in question. It represents a continuation of those studies of the mechanism of cellular growth which have been carried on for some time in the laboratory by means of the tissue culture method.

It was during the course of the early part of this study that the author noticed certain peculiarities in the structure of the nail in the region of the lunula which have appeared to be important in conditioning its opacity. Since the lunula itself has a certain clinical as well as a morphological importance, and since these particular structural peculiarities have not hitherto been emphasized as important in the anatomy of any part of the body, although probably very significant as a part of the general mechanism of the growth of this structure, it became of interest to report them in a separate communication.

The nails of the hands of five individuals have now been studied. They have included those of two adult white men, an adult negro woman and two white children. Lunulae were noted at the base of uncovered portion of the body of the nails of all the fingers of the white men and on the thumbs of the children. None was seen on any of the fingers of the negro woman before the epitrichium had been removed. When the epitrichial layer is lifted, however, the sharply defined opaque lunular zone is seen. It is present in all the fingers of this individual.

A number of these fingers were dissected at once. Others were fixed in formalin, dehydrated and decalcified. The blood vessels of a number of the fingers were injected with India ink. These fingers were likewise fixed in formalin, dehydrated and decalcified. The fingers which had been fixed were either embedded in colloidin, sectioned and stained or they were sectioned free hand, examined at once and later after they had been cleared. All the unfixed fingers were hemisected along the

median sagittal plane. This was accomplished by first cutting through the nail and the soft parts with a sharp knife, the bone being later cut through with a fine saw.

In every one of these fingers examined it has been noticed that the matrix of the nail underlying the lunula is not firmly adherent to the connective tissue stratum. Throughout the whole lunula area, the two layers do not apparently adhere but lie only in contact with each other. The slightest distortion of a sagittal section of the finger leads to the separation of these two layers. The open space thus formed is sharply circumscribed. It extends from the tip of the root of the nail, at which point the matrix is adherent, to a line which corresponds to the distal margin of the lunula zone. Beyond this line and over the whole body of the nail the matrix is firmly adherent to the underlying connective tissue layer (figs. 1 and 2).

The connective tissue underneath the lunula is peculiar in structure. The fibrils near its outer edge run parallel to the lower margin of the nail matrix. They form a dense boundary layer or sheath. The connective tissue here is not vascular. The capillaries are reduced largely to a single or double layer which lies close to, and on the surface of this layer of connective tissue. The underlying portions of the connective tissue contains few capillaries.

The matrix is also peculiar in this region. Its lower margin is in most parts straight. One sees very few indentations or papillary extensions into the underlying connective tissue. This is in sharp contrast to the outer pink portion of the nail body. Here the matrix is indented both longitudinally and transversely by connective tissue papillae. The connective tissue in this region is also strikingly different from that of the lunula. It contains many vertically placed fibrils which end directly at the edge of the epithelial cells of the matrix. They adhere closely to these cells or a basement membrane. The papillae as well as the neighboring portions of the connective tissue contain large numbers of capillaries. They form a dense network which fill the papillae and neighboring parts of the connective tissue. This dense capillary network is continuous with that

of the lunula portion, the change from one form into the other taking place gradually under the distal margin of the lunula.

A number of the nails of the fingers examined have been removed by stripping them back from their outer tip. By this procedure it is possible to remove the nail with the matrix of the

Fig. 1 A thick sagittal section of the finger of a white man. A piece of paper has been passed through the opening between the matrix and the connective tissue.

Fig. 2 A thick sagittal section of a finger of a white man which has been fixed, dehydrated and decalcified. The open space between the matrix and the connective tissue layer is readily discernible in the area corresponding to the lunula.

lunula attached to it. Throughout the body of the nail the matrix is invariably torn. In none of the nails thus removed has the lunular portion been found to be more opaque than the remaining portions. Quite the reverse, this area is frequently more translucent. In a number of the nails which had been

previously fixed, dehydrated and decalcified, the tip of the root does show a definite opacity. In none of these cases, however, is this opacity seen as far forward as the distal margin of the lunular area. It fades and gradually disappears a short distance distal to the tip of the root. Furthermore, this opacity is not noticed in all the fixed specimens.

From these latter observations it seems evident that the opacity of the lunula is not conditioned by any peculiarity of the structure of the nail itself nor its matrix. Moreover, that the decrease in the capillary bed of the lunular area is not wholly, if at all, responsible for the opacity may be deduced from the fact that its change in density at the distal margin of the lunula is never as abrupt as the boundary line of the lunula demands. Further proof against this peculiarity playing any important rôle in conditioning the opacity is given by comparing the appearance of the lunular area with a portion of the body from which the blood has been removed by pressure. The lunula has a definite opacity, while that portion of the body from which the blood has been removed has a greyish translucency.

In the absence of other possibilities, the author has been led to believe, therefore, that the lunular opacity is the result of a reflection of the light at the surfaces of the junction of the matrix and the connective tissue of this portion of the nail. In the outer portion of the nail where the matrix adheres closely to the underlying connective tissue the light is transmitted directly to the capillary bed giving it its characteristic pink color; while in the region of the lunula the well formed non-adherent surfaces of both the connective tissue and the matrix reflect the light. More direct proof of this assertion may be readily obtained by pulling a portion of the body of a living nail loose from the connective tissue, thus forming such a surface in this region. During the past few weeks the author has been performing work which has led to the production of this injury. In each instance when it has occurred the detached portion has shown an opacity quite indistinguishable from the opacity of the lunula of the same finger. It is of interest, however, that unless the injury is extensive the nail will again after a few hours become adherent and assume its former pink color.

The decrease in the capillary bed of the lunular area has been described (Poirier and Charpy, Traité d'anat. hum., Paris, 1901). No one, on the other hand, as far as the author has been able to determine, has described the peculiarity of adhesion between the matrix and the connective tissue in this region, nor the relation of this peculiarity in structure to the lunular opacity. It will be of further interest to ascertain whether many of the pathological opacities of the nail are not the result of similar changes, and to study more carefully the conditions which lead to the adhesion of the matrix in outer portion as contrasted with that of the lunular zone, and the general changes in the connective tissue and in the arrangement and density of the capillaries in these two regions. The nail is one of those peculiar parts of the body which continues to grow throughout the whole life of the body. A more careful investigation of its general structure and the chemical and physical changes which accompany its growth may lead to many facts of importance for ultimately ascertaining those conditions which bring about and regulate the growth of other body structures.

A PRELIMINARY EXPERIMENTAL STUDY ON THE RELATION BETWEEN MITOCHONDRIA AND DISCHARGE OF NERVOUS ACTIVITY

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We have heard a great deal about mitochondria in nerve cells, but unfortunately their study has not emerged from the purely descriptive into the experimental stage. The only record of experimental work on mitochondria in the nervous system is a brief note by Luna ('13, p. 415) on the changes in mitochondria in nerve cells following section of their peripheral processes. He found that the first changes consisted in a loss of the regular distribution of mitochondria, in an increase in their volume and in an increase in their affinity for iron hematoxylin; while in the more advanced stages of degeneration the mitochondria disappeared completely. Archimede Busacca ('15, p. 232), working on the eye, found that mitochondria in the nerve cells of the retina increased in number on light stimulation. Accordingly it is a very pertinent question to inquire whether there are alterations in mitochondria of nerve cells in muscular fatigue.

White mice were selected for the experiments because they are the smallest mammals which can be conveniently used in the laboratory and on account of the fact that more is known of the quantitative (Thurlow '16) and qualitative (Nicholson '16) variations in mitochondria in their nervous system than in that of any other animal.

They were fatigued by the very simple method, which Prof. Tamao Saito uses, of letting them swim in water until they are exhausted. It was soon discovered that they swim better when the water is slightly agitated and is raised to body temperature. Otherwise they soon learn to float and refuse to exercise.

The experiments were controlled in the usual manner by using only mice of known age and by examining, in exactly the same way, an unexercised mouse of the same litter for comparison. Five experiments of this kind were made, the mice swimming from one to two hours continuously before they were completely exhausted. (Larger mammals will swim for a day or more before exhaustion). Experience showed that young mice twenty-five to thirty days old are more suitable than adults because they are more easily tired.

In each of the five experiments the fatigued mouse and the control mouse from the same litter were chloroformed. They were then fixed by the injection of a formalin and bichromate mixture in accordance with the method advised by Cowdry ('16, p. 34). The brains were removed, mordanted, washed, dehydrated and cleared together in the same bottle. They were embedded in the same block of paraffin. Sections, cut 4 μ in thickness from the fatigued and from the control, were mounted on the same slide so as to avoid variations in the staining which might otherwise occur. The sections were then stained with fuchsin and methyl green, the fuchsin coloring the mitochondria crimson and the methyl green staining the Nissl substance a bluish green color. Preparations were made in this way of the cortex, the cerebellum and the spinal cord from each of the five experiments.

The mitochondria show a slight numerical increase in the fatigued animals in three of the experiments, but the other two experiments do not show it, indeed, in one of them there is a definite decrease in the number of the mitochondria; in any case, the variations in the number of mitochondria fall well within the range of variation which was found to be normal for the species.

Neither could any definite change in the form of mitochondria be seen in the fatigued animals. True, in the Purkinje cells of the cerebellum some of the mitochondria were swollen up to form spherules (0.5 μ to 1 μ in diameter), but, on careful examination some of the controls showed examples of the same phenomenon, though in less marked degree.

There was a tendency toward a clumping of the mitochondria in the cytoplasm of the fatigued animals as contrasted with the more or less uniform distribution in corresponding nerve cells of the control. This clumping, when it occurs, is particularly apparent in Purkinje cells at the base of the large dendrite in close relation with the 'capuchon chromatique' of Cajal.

The Nissl substance is well fixed and is stained brightly with methyl green by the technique employed. A mild degree of chromatolysis was noticed in all the fatigued animals, in variable amount. It was usually most marked in the Purkinje cells of the cerebellum and in the pyramidal cells of the cortex. This would be inclined to lead one astray were it not for the fact that one of the normal control animals showed just as extensive chromatolysis if not more extensive than any of the fatigued ones.

Vacuoles and clear, tortuous, unstained canals (the canalicular apparatus of authors) were of common occurrence in both the fatigued and the control brains. In two of the experiments they were certainly wider and more clearly cut in the anterior horn cells of the fatigued than in those of the normal, but, again, this difference was not apparent in the other three.

The nuclei and nucleoli were given careful attention and proved entirely negative as far as a definite change is concerned in the fatigued animals. Unfortunately preparations were not made by the neurofibrillar methods and by the positive methods for the demonstration of the Golgi apparatus.

Chromophile cells could be seen in both the fatigued and the control brains. They were never observed except in the higher centers, that is, the cerebral cortex and the cerebellum. The chromophile cells stained uniformly red with fuchsin (Cowdry '16, p. 36). If anything, they were slightly increased in number in the fatigued animals.

It is evident, therefore, that the net result of these five experiments, with their controls, is to show that the mitochondria are surprisingly constant in nerve cells, rather more so even than the Nissl substance which is supposed to be concerned with the activity of nerve cells 'per se.' A fair degree of fa-

tigue, as well as a certain amount of fright, brings about no constant changes in them. It is certainly no longer necessary to take elaborate precautions in composing the minds of animals before killing them for studies on the mitochondria in the central nervous system. It is quite possible that more prolonged exhaustion will lead to definite and precise alterations in mitochondria in nerve cells. But it would appear that the study of mitochondria in fatigue in muscle cells, thrown into isometric tetanus outside the body, is more likely to bring about changes in them.

Mitochondria occur in all nerve cells though we have very little idea of what their true significance is. Certain it is, however, that they are stable structures which are not essentially altered with slight fatigue. They are not associated with the specific activity of the nervous system, that is to say with the explosive discharge of the nervous impulse, any more than they are concerned with the elaboration of secretion in pancreas cells. Key ('16, p. 216) found that the mitochondria are not exhausted in the acinus cells of the pancreas by even prolonged stimulation with secretion and pilocarpin.

This independence of mitochondria of the specialized activities of cells is in general accordance with the views which have been expressed by many authors to the effect that they are concerned with the basic fundamental processes of metabolism (some hold with oxidations) which all cells possess in common. In fact this is the conclusion to which Cowdry ('14, p. 17) has arrived in the case of the nerve cell.

It also falls in line with the generally recognized fact that with starvation and other influences which bring about changes in metabolism, the nervous system is more difficult to alter than any other tissue in the body; as well as with the unsatisfactory results which have usually attended attempts to alter the metabolism of the nervous system through excessive mental work and other agencies. I refer to the calorimeter experiments of Benedict.

Furthermore, these processes of metabolism are, as one would naturally expect, very easily modified in pathological states;

hence the sensitivity of mitochondria to pathological change. Scott ('16, p. 250) discovered that the mitochondria are the first of all the cell constituents of the pancreas to become altered in experimental phosphorus poisoning. Moreover, the fact, which is now emerging from the numerous recent pathological studies on mitochondria, that mitochondria in different types of cells respond in much the same way to different varieties of injurious influences, in other words, that there is nothing specific in the reactions of mitochondria to pathological change, is also in accord with the prevalent conception that they take part in a type of activity common to many cells.

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AN ANOMALOUS VENA PULMONALIS WITHIN THE LUNG

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From the Anatomical Laboratory of the University of Wisconsin

TWO FIGURES

Anomalies in the distribution of the Venae pulmonales within the lung, so far as the author has been able to discover, have not been described. The only cases which he has been able to find were extra-pulmonary, and were either variations in the fusions of the venous trunks before entering the atrium sinistrum of the heart, or aberrant veins which emptied into the Vena cava superior, the Vena cava inferior or some one of their branches.

While making a series of study corrosions of the blood vessels of the lung of the dog and their relation to the bronchial tree, Professor Miller called my attention to an anomaly within the lung which seems to be unique.

The lung of the dog consists of four lobes on the right side and of two on the left side. The lobus superior (oral) of the left side is incompletely subdivided into two lobes by a deep notch. The first of these I shall, for convenience of description, designate the apical lobe; the second, the left cardiac lobe. The first hyparterial branch given off by the left bronchus almost immediately divides (figs. 1 and 2) into two main branches which pass, the one to the apical lobe (the apical bronchus), the other to the left cardiac lobe (the left cardiac bronchus).

In the normal lung the blood is returned from the left lobus superior (fig. 1) by two main venous trunks which are situated ventral to, and slightly removed from, the corresponding branches of the bronchial tree. In the angle between the two main bronchi a small vein is seen (fig. 1) which returns the blood from a portion of the first branch given off by the apical bronchus. This vein passes behind (dorsal to) the bronchial

stem going to the aboral portion of the lobus superior, the left cardiac lobe, and joins the main venous trunk which accompanies this bronchus. It is necessary to note carefully the origin and position of this small vein, for it apparently plays an important rôle in explaining the course of the anomaly.

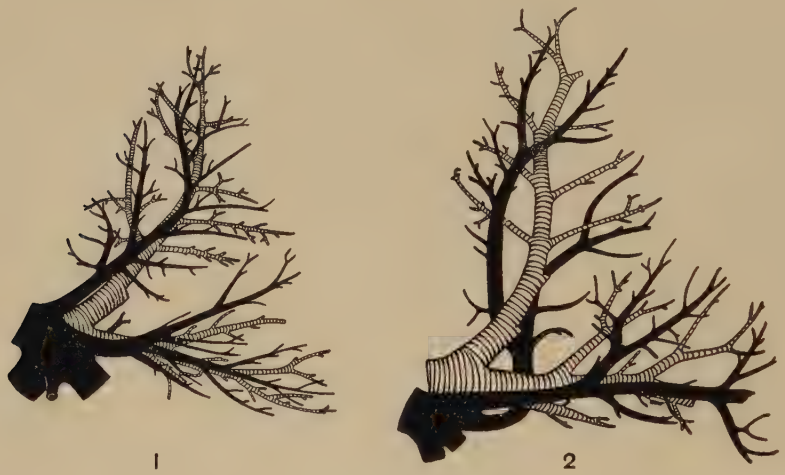

Fig. 1 Celloidin corrosion of the lobus superior of the left lung of a dog showing the normal distribution of the Venae pulmonales and their relation to the apical bronchus and the left cardiac bronchus. Note the small vein in the angle between the two bronchi. Its connection with the cardiac vein is not shown. In this figure and in figure 2 some of the bronchial branches have been omitted for the sake of clearness.

Fig. 2 Celloidin corrosion of the lobus superior of the left lung of a dog in which an anomalous distribution of the Venae pulmonales was found in the apical lobe. Note how the apical vein forms half of a spiral turn about the bronchus and eventually joins the vein coming from the aboral portion of the lobus superior.

The first portion of the anomalous vein follows closely the course of the normal vein; but as soon as the two distal radicles have united the vein swings away from the bronchus towards the facies mediastinalis (fig. 2). It then passes dorsal to the Arteria pulmonalis and the bronchus forming half of a spiral turn about these structures, and passing dorsal to the left cardiac bronchus, empties into the vein which accompanies the latter.

Only one small branch joins the lateral side of the vein throughout its unusual course. On the mesial side the branches have a normal arrangement. As the vein curves behind the artery and the apical bronchus it is joined by a branch of considerable size which is formed by venous radicles coming from the area that is usually drained by branches which join the lateral surface of the apical vein, when it takes its normal course, and by radicles which normally form the small vein found in the angle between the apical bronchus and the left cardiac bronchus. The trunk formed by the union of these two branches follows, as stated above, the course taken by the small vein found at this point in the normal distribution of the veins.

The following explanation of the anomaly seems to be the rational one. During the development of the pulmonary venous system some obstruction to, or atrophy of, the vessels which usually form the apical vein took place. Changes were thus brought about in the capillary bed and secondary trunks were formed which connected with the small vein present in the normal condition in the angle between the apical bronchus and the left cardiac bronchus; as a result this vein became the main trunk and returned all the blood from the apical bronchus.

THE ANATOMY OF A DOUBLE PIG, SYNCEPHALUS THORACOPAGUS, WITH ESPECIAL CONSIDERATION OF THE GENETIC SIGNIFICANCE OF THE CIRCULATORY APPARATUS

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TEN FIGURES

INTRODUCTION

The following case of syncephalus or Janiceps asymmetros, is interesting on account of first, the unusual possession of two distinct hearts each contained in a separate pericardium; second, to the subsequent fusion of the aortic arches, of both hearts, with each other, in which there were persistency or degeneration of certain integers to form the anomalous condition of the circulatory apparatus; and third, to the possession of two complete cerebro-spinal axes.

According to Fischer ('04) there were 50 human and about 80 cases in the domestic animals of the syncephalus class, recorded in teratological literature. However, I have been able to find only one case of a double pig that shows a close resemblance to the specimen here dissected.

Wymann ('61) dissected a syncephalic pig presenting the following characteristics.

Extract

"A single head in which the nervous system is made up of the right hemisphere of one brain and the left hemisphere of the other with an intermediate compound one. There is a single optic thalamus and striated body, below this the nervous system is double with a distinct cerebellum for each lateral cerebral hemisphere and two spinal cords. The head possesses two lateral ears and a posterior compound one. There are three nostrils on the snout. There are two sets of upper extremities. The body is fused from above downwards to the umbilicus; from the latter point the compound body divides into a right and left body with two distinct sets of inferior extremities. The thyroid, lungs, liver, kidneys, spleen and genitals are double. The heart is compound. The alimentary canal tract is single to the lower one-third of the ileum and from there it is double."

The chief differences as will be noted in the following text from the above description by Wymann, will be found in the nervous system and in the heart. He does not describe the remainder of the blood vascular system, so no comparison may be made there.

In cases of complete dicephalus, there are found two distinct nervous systems in their cephalic aspect at least, and generally two hearts. But in no case in the literature on syncephalus, of the Janiceps asymmetros type, to which the writer had access, either in the domestic animals or in man, was he able to find a specimen recorded possessing two distinct cerebro-spinal axes, and two distinct hearts enclosed in separate pericardia with the anomalous condition of the blood vascular system as here found.

A few cases of double monsters in other domestic animals which show some external or internal feature in common with the double pig here studied are described by Dareste (52) in the cat, Gurlt ('32) cat, Mitchell ('90–'91) chick, McIntosh ('68) cat, Pilcher ('80) pup, Reese ('11) cat.

The following is a partial list of the cases consulted on syncephalus in man, Braun ('79), Caillé ('89–'90–'91), Debiene et Dutilleul ('90), Godson ('68–'70), Hilliard ('80), Hirst and Piersol ('93), Hue ('65–'70), Mayor ('81–'82), McLaurin ('80–'81), von Swiecicki ('87), Walter ('89).

The specimen that is the subject of this paper was given to the author in 1914 by Dr. J. S. Foote, professor of histopathology, Creighton Medical College. It was presented to the department of pathology by Drs. Sumney and Hellwig of Omaha seven years ago. From the degree of development of the external body form, the hair, extent of descent of the testicles, palpebral fissures and the foramen ovale, the monster corresponded to the appearance of a fifteen week fetus. The normal period of gestation for the pig is about one hundred and twenty days or roughly speaking seventeen weeks.

The specimen was covered entirely by white hair and weighed 500 grams. The right body is longer than the left one as can be verified by reference to the skiagraph, figure 9. The former measured 20 cm., the latter 18 cm. in the crown and rump line.

TOPOGRAPHICAL ANATOMY

Ventral aspect (fig. 1). It is readily apparent that the heads of the monster were turned laterad, the left head to the left and the right one to the right, and fused to form a single compound head with a ventral compound face and a dorsal rudimentary one. The larger ventral compound face is made up of the right side of one head and the left side of the other. The snout has four nostrils. The two well formed ones belong to the left head and the two rudimentary ones belong to the right. The left and right eyes belong to the left and right heads respectively.

The bodies are joined venter to venter. The fusion extends cephalo-caudad to the umbilicus from which point caudad the bodies are distinct and normal. There is but one umbilical cord which contains four arteries, and two veins. This cord is located on a plane mesiad between the two bodies rather than on a plane passing dorso-ventrad through the ventral thoracopagic region. These vessels are distinct

Figure 1

for the remainder of the cord left intact with the monster; which was for a length of 6 cm.

External examination proved both bodies to be males; this being verified upon dissection.

Dorsal aspect (*fig. 2*). Upon the mesio-cephalic aspect of the fused heads is seen an oval pit devoid of hair which marks the end of the proboscis of a cyclops; this proboscis was formed by the fusion of the

right eye of the left head and the left eye of the right one. At the base of the skull a pair of small ears of the dorsal face are found close together, which bear the same relationships to the compound skulls as do the eyes. The two dorsal fore limbs are separate integers, the left being the right fore limb of the left body and the right the left fore limb of the right body. The two separate bodies below the bifurcation of the monster are normal.

Figure 2

INTERNAL ANATOMY

Although the muscles were dissected and studied, no attempt will be made to record here the detailed findings.

Respiratory, digestive and genito-urinary systems (*fig. 3*). There was a ventral and a dorsal pair of lungs. The former possessed a three lobe right and a two lobe left lung; the latter, a three lobed left and a

two lobed right lung. Each pair of pulmones is composed of integers heterogeneous in origin. The ventral pair comprises the right and left lung of the right and left bodies respectively; the dorsal, of the left and right lung respectively of the right and left bodies. Each pair of lungs possesses a corresponding trachea which leads cephalad into its respective larynx. Each of the latter was surmounted by an epiglottis. The larynges were at the same level on a mid-dorso-ventral line.

The tongue was compound. At the location of the foramen cecum of the right integer there was a pedicle 1 cm. long; on the distal end there was located a globular structure. Upon section this proved to be thyroid glandular tissue. The left thyroid gland was present but the right was absent from its normal locations in the neck. Cephalad the opening into the oesophagus was located between the two larynges. The alimentary tract was single to within 16 cm. of the cecum. At the former point the ileum bifurcated, each integer leading to its respective ileo-cecal valve. However, this single tract possessed a much larger ileum than is normally found even in a post-partum pig of two or three weeks of age. Each portion of the now double alimentary tract was normal for its corresponding body.

There were two livers the right being larger than the left. These were located considerably more caudad than normally. The common bile-duct from each gall-bladder was joined by the pancreatic duct of the same side 0.25 cm. before the entrance into the duodenal wall. There was a normal pancreas for each body.

The genito-urinary system was double each entity being normal. The testicles were undescended all four being located respectively in an inguinal canal just internal to the external abdominal ring.

CIRCULATORY SYSTEM

Ventral aspect (*schematic* (*fig. 4*)). There was one large heart situated ventrad within the thorax in a separate pericardium. Dorsad and to the left was found a heart one-quarter of the size of the ventral one. The former evidently had been crowded into the position it occupied in the right portion of the thoracic cavity of the left body by the much larger and more vigorous ventral cor. The smaller one also possessed a separate pericardium. The auricular cavities of each heart were normal in structure. However in both, the auricles were connected by an abnormally enlarged foramen ovale due to the failure of complete development of the septa prima and secunda. The ventricular cavities of both inter-communicated due to the lack of development of the interventricular septa.

The large ascending aorta of the ventral heart bifurcated 1.5 cm. from its origin into a larger right aortic arch and a smaller left one. At the junction of the left aortic arch with its corresponding ductus arteriosus, the left and right subclavian arteries of the left body are

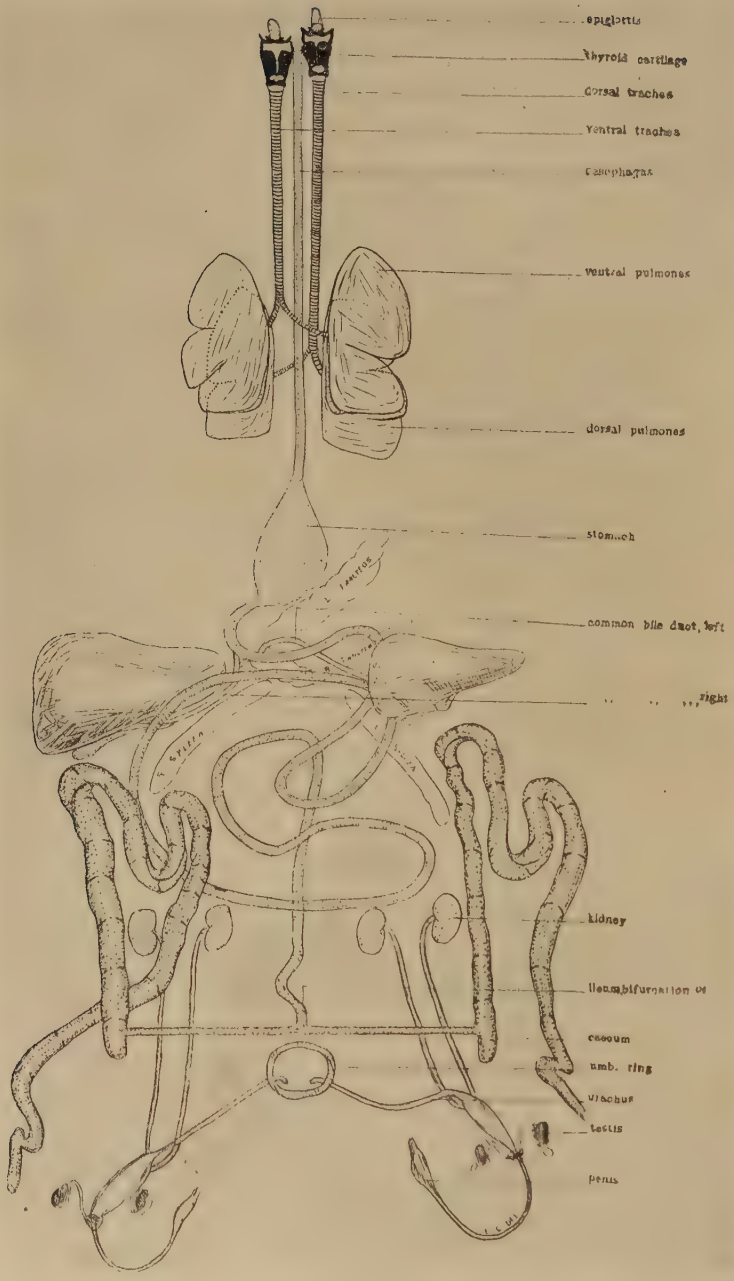

epiglottis
thyroid cartilage
dorsal trachea
ventral trachea
œsophagus
ventral pulmones
dorsal pulmones
stomach
common bile duct, left
" " " right
kidney
ileum bifurcation of
cæcum
umb. ring
urachus
testis
penis

Figure 3

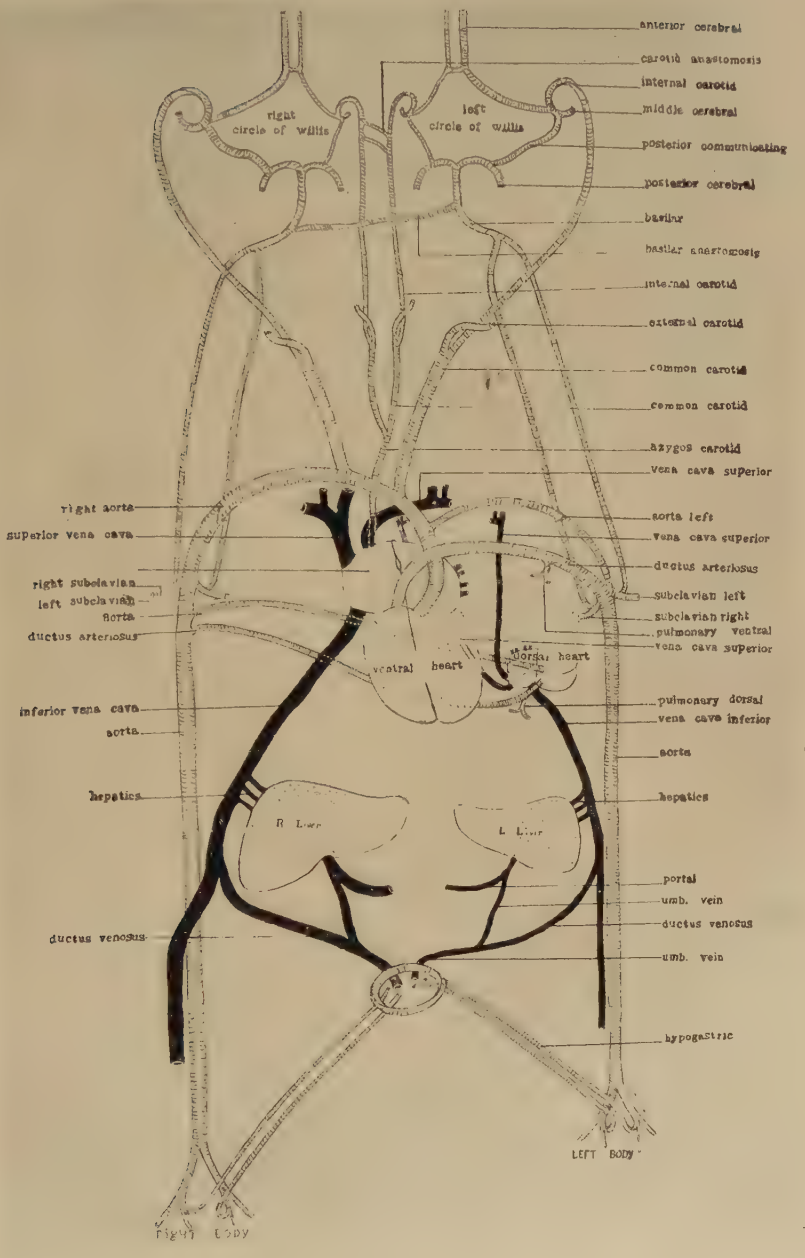

anterior cerebral
carotid anastomosis
internal carotid
middle cerebral
posterior communicating
posterior cerebral
basilar
basilar anastomosis
internal carotid
external carotid
common carotid
common carotid
azygos carotid
vena cava superior
right aorta
superior vena cava
right subclavian
left subclavian
aorta
ductus arteriosus
aorta left
vena cava superior
ductus arteriosus
subclavian left
subclavian right
pulmonary ventral
vena cava superior
ventral heart
dorsal heart
inferior vena cava
aorta
pulmonary dorsal
vena cava inferior
aorta
hepatics
hepatics
R Liver
L Liver
portal
umb. vein
ductus venosus
ductus venosus
umb. vein
hypogastric
LEFT BODY
RIGHT BODY

Figure 4

given off. Coming from the latter arteries their respective vertebral branches are found.

The right aortic arch of the ventral heart, just proximal to its junction with the left aortic arch of the dorsal heart, gives off the right and left subclavian arteries of the right body. From the latter vessels their corresponding vertebrals are derived. One cm. caudad to the junction referred to above, the ductus arteriosus of the dorsal heart joins the descending aorta of the right body. The latter vessel, as will be seen later, belongs genetically to the dorsal heart.

From the left aortic arch of the dorsal heart a single vessel arises which is called here the azygos carotid. Four cm. from its origin it bifurcates into the two common carotids. The internal carotids of these latter vessels, go to form the mesial aspects of their respective circles of Willis. The left aspect of the left circle of Willis and the right aspect of the right circle of Willis derive their vascular supply from the internal carotids which are branches of the common carotids of the right aortic arch of the ventral heart.

Four hypogastric arteries leave the umbilical ring, one from each of the four internal iliac arteries. There are two umbilical veins which are distributed normally one to each body.

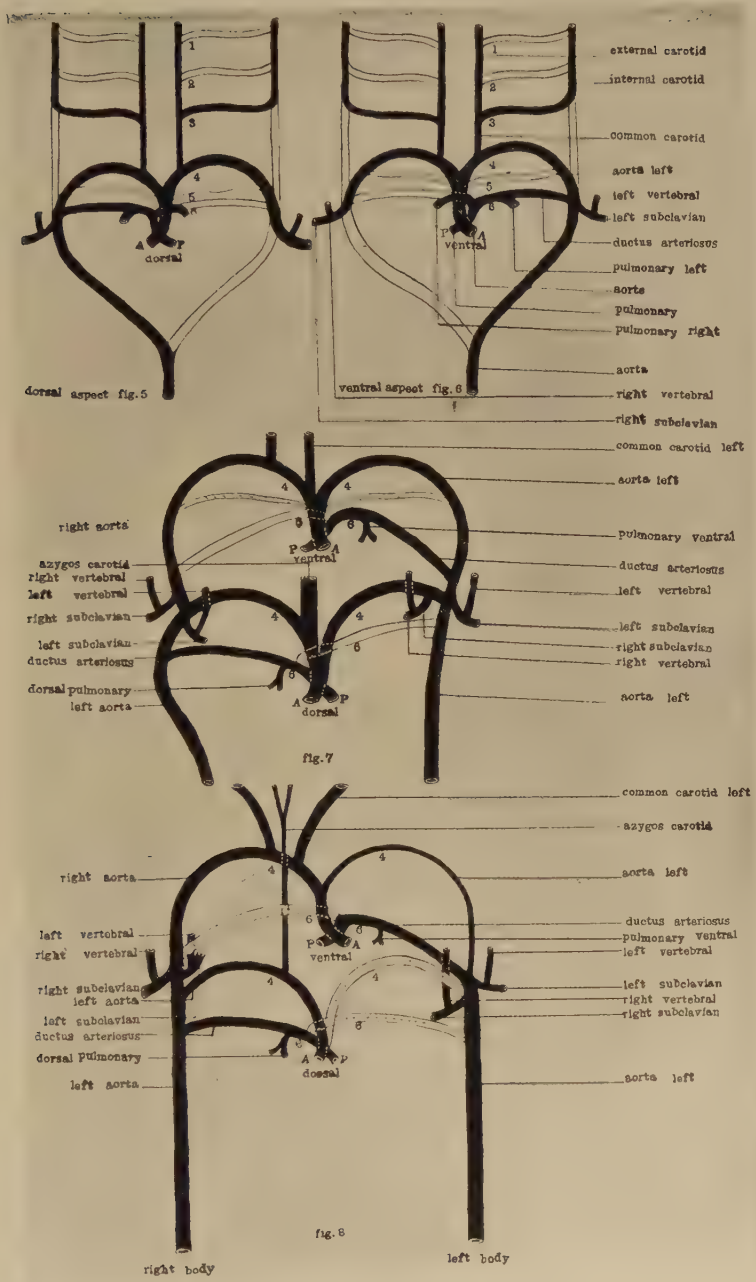
The intercostal and lumbar arteries although not depicted in figure 4 are distributed in a normal manner from each descending aorta.

There are two spleens.

Genetic significance of the circulatory apparatus (*figs. 5, 6, 7, 8*). In order to simplify the understanding of the means by which such an anomalous condition of the circulation was formed, it will be necessary, in the first place, to consider the normal aortic arches of two hearts as presented in figures 5 and 6. The former depicts the normal arches of a heart from the dorsal aspect; the latter those from the ventral view. In the fusion of two embryonic areas or the splitting of a single one to form the monster, the bodies were ultimately brought venter to venter and conjugated; as a consequence the ventral surfaces of each set of arches were brought into apposition.

After the fusion and the resultant abnormal alteration of origin of some of the large vessels, we then would have the condition of the circulation as represented in figure 7. Here we find the right and left aortic arches of each heart still persisting. Two common carotids come off abnormally from the right aortic arch of the ventral heart and a single trunk called, as previously stated, the azygos carotid, from the left aortic arch of the dorsal one. It is important to remember that genetically the right common carotid of the right aortic arch of the ventral belongs to the dorsal heart; and that the smaller left common carotid of the azygos carotid of the dorsal heart belongs to the ventral one. As schematically shown, the subclavian arteries are still branches of their respective right and left arches.

In figure 8, we find the complete degeneration of the proximal portion of the right aortic arch of the dorsal heart; the subclavian artery of this vessel is now a trunk of the descending aorta of the ventral


dorsal aspect fig. 5
ventral aspect fig. 6
external carotid
internal carotid
common carotid
aorta left
left vertebral
left subclavian
ductus arteriosus
pulmonary left
aorta
pulmonary
pulmonary right
aorta
right vertebral
right subclavian
common carotid left
aorta left
pulmonary ventral
ductus arteriosus
left vertebral
left subclavian
right subclavian
right vertebral
aorta left
right aorta
azygos carotid
right vertebral
left vertebral
right subclavian
left subclavian
ductus arteriosus
dorsal pulmonary
left aorta
fig. 7
common carotid left
azygos carotid
right aorta
aorta left
ductus arteriosus
pulmonary ventral
left vertebral
left subclavian
right vertebral
right subclavian
left vertebral
right vertebral
right subclavian
left aorta
left subclavian
ductus arteriosus
dorsal pulmonary
left aorta
aorta left
fig. 8
right body
left body

heart and supplies the right extremity of the left body. The left subclavian of the left aortic arch of the dorsal heart is abnormally a branch of the first part of the descending aorta of the ventral heart and furnishes the blood supply to the left extremity of the right body.

From the above embryological consideration it is seen that the larger ventral heart belongs genetically to the left body whereas the smaller dorsal heart belongs to the right body. However, the dorsal heart has been rotated and crowded from its earlier position into the right side of the thoracic cavity of the left body by the larger and more vigorous ventral heart. The ventral surface of the dorsal heart is now directed ventrad, in reference to the double monster, instead of dorsad. As a consequence the relationship of its great vessels is considerably altered.

The right and left aortic arches of the ventral heart have persisted, the right being considerably the larger of the two as previously pointed out. The right by joining the descending aorta of the dorsal heart form a good size trunk, slightly larger than the left one. This is due to the fact that both hearts contribute to the descending aorta of the right body and only the smaller left aortic arch and its corresponding ductus arteriosus of the ventral heart go to form the descending aorta of the left body. It is therefore clearly seen that the right and larger body receives the greater blood supply, "due to the influences which have brought about a more abundant growth of capillaries," Evans ('12).

Developmentally the vessels of the dorsal heart supply the right side of the left body and the left side of the right body whereas those of the ventral one, supply the left side of the left body and the right side of the right body. In other words, the larger ventral heart supplies the ventral aspect of the syncephalo-thoracopagic regions, of the double monster and the smaller dorsal heart genetically contributes the vessels distributed to the dorsal aspect. In the lumbar, pelvic and caudal extremities of each body, the vessels are normally distributed.

The same conditions that governed the relationship of the areas supplied by the arteries of the ventral and dorsal heart ruled over the veins draining those regions. However, the entrance of the veins can be traced to their respective hearts, whereas on the other hand, the genetic relationship at first is somewhat obscure and blotted out in regard to the arteries. Each heart possesses two superior venae cavae representing the persistent anterior cardinal veins which emptied separately at the right and left lateral poles of the sinus venosus.

Although figures 5 and 6 are schematically represented as normal arches, it is by no means the intention of the writer to convey the impression that two absolutely normal aortic arches, developed to the stage as here represented, were necessarily at one time existent, or that fusion took place at this late period in development. The establishment of this anomalous circulatory apparatus was no doubt forecast in the fused capillary net-work which was the anlage of the abnormal

condition of the arches as shown in figure 8. The early indifferent endothelial vascular network of each heart fused and then the elaboration of the main trunks as depicted in figure 8 represent a physiological adaptation of this fused network to the demands of the circulation in the monster. The fortuitous location of certain channels of the net with regard to the aorta of either heart determined the enlargement and use of these paths to form the normal and abnormal vessels. It was merely for the sake of simplicity to emphasize the venter to venter apposition and fusion of the anlage of each set of aortic arches, that two developed normal sets are used in diagrams, instead of the complex antecedent network of each. As a consequence correct sequence of development of the vessels was sacrificed for simplicity.

THE SKELETON

The posterior extremities, pelvis and lumbar vertebrae were normal for each body. In the dorsal region of the left vertebral column, from the third to the ninth dorsal vertebrae, kyphosis is presented. This is undoubtedly the cause for the shorter length of the left body.

The thorax was compound, the sternum and ventral ends of the ribs of each side were so reflected and fused with their corresponding parts of the other as to form one large thoracic cavity bounded by fifty-six ribs; fourteen on the lateral aspect of each body. Each sternum, dorsal and ventral, has a double origin as is apparent from the reflection considered above. Only the upper seven ribs were attached to either sternum. The remaining seven were absolutely free, having neither cartilagenous nor bony connections at their distal ends. The thoracic appendages were normal in structure. However, the ventral pair were better developed than the dorsal pair.

The spinous processes of the cervical vertebrae were directed laterad instead of dorsad which fact may readily be verified by a reference to the skiagraph, figure 9.

The skull is compound. This is apparent for each vertebral column has its separate occipital attachment. In the fusion the interior of the compound cranium was left double. The right temporal, parietal, frontal, nasal, parietal maxillary and lateral aspect of the occipital bones of the left skull fused with the corresponding parts of the right one, to form an attenuated partition between the left and the right encephala. This line of fusion may be seen from the exterior extending through the oval depression marking the point of emission of the proboscis of the cyclops, marked *2*, figure 10. The two opposed orbits were fused to form the condition of synopthalmia. The partition did not leave the normal amount of space for the development of each brain; this is apparent by the fact that the mesial hemisphere of each encephalon is smaller than the lateral one. The adjacent walls of the mesial hemispheres present parallel surfaces instead of being normally convex.

Figure 9

Fig. 10 Cerebro-spinal axes. Dorsal aspect. *1*, olfactory bulb; *2*, proboscis of the cyclops; *3*, right cerebrum; *4*, cerebellum; *5*, medulla oblongata; *6*, cervical swelling; *7*, lumbar swelling; *8*, cauda aquina.

CEREBRO-SPINAL AXES

There are two encephala in the double compound cavity. Each brain and stem is distinct, there being no fusion. However, the right optic nerve of the left encephalon and the left one of the right encephalon do fuse to form a compound trunk. This terminated in a small amorphous structure which represents the fused eyes of the cyclops, marked *2*, figure 10, as referred to above. The optic nerve of the right lateral normal eye belongs to the right encephalon; that for the left lateral normal eye is derived from the left encephalon. Neither is seen in figure 10, due to the fact that the cerebrospinal axes were so placed that the center of focus would fall on the synophthamia. Each encephalon as a result obscured its corresponding lateral eye from view. The remainder of the cranial nerves were distinct and separate. Except for the optic fusion as here considered, there is no other connection between the cerebro-spinal axes.

The effect of kyphosis of the dorsal vertebrae on the contained cord is readily apparent in figure 10. The marked loop to the left in the left spinal cord in the upper dorsal region is clearly seen. In actual measurement both cords have the same length. The shortening is due to the loop caused by the kyphosis circle of Willis.

Each heart contributes blood to each encephalon as was seen above. The dorsal heart furnishes the blood supply to the mesial aspects of each circle of Willis, whereas, the ventral heart furnishes the blood to the lateral aspect of each circle of Willis.

In conclusion, I wish to express my sincere thanks to Dr. Foote for the specimen here recorded and to Dr. Tyler, professor of Roentgenology of Creighton Medical College, for the skiagraph of the skeleton, figure 9.

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A DEVICE TO INCREASE THE EFFICIENCY AND EASE OF MANIPULATION OF THE FINE ADJUSTMENT OF THE MICROSCOPE

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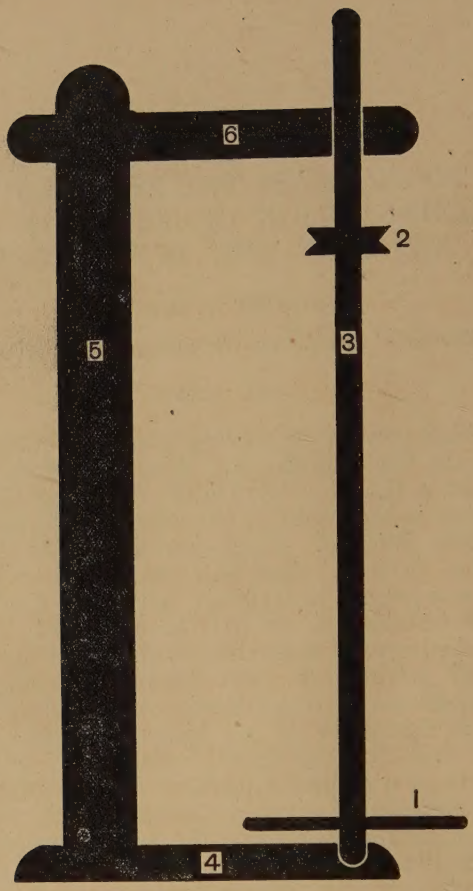
ONE FIGURE

The use of high powered microscopic lenses requires the hand to be constantly on the fine adjustment. When the study is continued for several hours at a time the hand and arm doing the focusing, even though the latter is supported at the elbow on the table or chair arm, become extremely fatigued. To obviate this strain the apparatus figured below was devised. Although the role it was originally intended to fill was merely to facilitate the use of the fine adjustment, it has, since its installment, not only been of aid in this way but has greatly diminished several annoying features that are frequently connected with high power work. For this reason it seemed worth while to bring the attachment to the attention of microscopists.

The device as figured is for use with microscopes which have the more common 'top' fine adjustment although it would be a simple matter to construct a similar apparatus for use with the side wheel type. No dimensions are given, as these must be controlled by the height of the particular microscope the attachment is intended to be used with. The illustration, which is a side view, is just one-half the size of the one I have in use. The entire apparatus is made of wood and it is simpler to use dowel sticks of various diameters for the pillar (*5*), the arm (*6*), and the shaft (*3*), although other material could be used satisfactorily. The focusing wheel (*1*) is a disc cut from lumber about one-eighth of an inch thick. It is of advantage to have this wheel large (two to two and one-half inches) and thin, so that it may be easily gripped and turned with either the thumb or fingers. The edge of this disc is rounded and notches are filed into it at intervals of about one-quarter of an inch to prevent the fingers gripping it from slipping. The grooved wheel (*2*) is made by gluing together two discs about one inch in diameter (cut from thin lumber) whose adjacent rims have been beveled. It is well to have the channel or groove rather deep so as to prevent the belt from jumping when the microscope is inclined.

Care, of course, must be taken to center the hole in the arm (*6*) through which the shaft (*3*) passes and the socket in the base (*4*) into which the end of the shaft slips. Smoothness of action is obtained by soaking that part of the shaft that is in contact with the arm, and the hole in the arm through which the shaft passes, with paraffin. The socket in the base is filled with paraffin so that the shaft is resting in a



tightly packed bed of this material. I am indebted to Dr. C. E. McClung for suggesting this method of lubrication, which results in a very soft, smooth movement.

In use the apparatus is screwed to the table (in my case to the drawing board on which the microscope rests) with the pillar (*5*) away from the observer. A belt composed of string which will not stretch (such as braided fish line) is passed around the pulley (*2*) and the focusing wheel of the microscope. The microscope may be used in any position. The focusing arm lies flat on the arm of the chair or the table and the focusing wheel (*1*) is within easy access.

Since the pulley (*2*) is made smaller than the fine adjustment wheel of the microscope the sensitiveness of focus is increased. The delicate focusing of high powers has been found to be much steadier with this attachment. The annoying feature of the field under observation being a trifle displaced while drawing, due to the hand on the focusing wheel jarring the microscope (however little), is largely eliminated with the use of the device described as it is now unnecessary to directly touch any part of the microscope.